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Table Of Contents

Page 542: Mind and consciousness - is materialism true? By Reyansh Sinha

Math Circles: A New Solution By Joshua Wang

The United States is falling behind in math and education. Programme for International Student Assessment–PISA and National Assessment of Educational Progress–NAEP scores, scores that are utilized to measure fundamental skills in math, have been dropping in the United States for the last several years: a result undoubtedly from the incomplete and lackadaisical nature of American mathematics education. Modern day students are being drilled the same ideas over and over in a monotonous, stress inducing classroom that places too high of an emphasis on testing, instead of instilling passion in math, and those that are proficient in math are held down from their potential by the rigid, strict curriculum that American Mathematics education offers. In light of these new low scores seen throughout American schools, extensive research has shown that flipped, nontraditional classrooms and styles of teaching–such as Math Circles, unique collaborative math classrooms and spaces–could lead to a revival in the strength and learning retention within Mathematics education and Pedagogy.

Mathematics classrooms in American schools today are largely ineffective. Specifically, a weak building and lower understanding of fundamental math at a young age leads to a huge disadvantage for many students later on in their academic and professional careers. In school, students are expected to perfectly remember every previous unit and aren't given much opportunity or time to question the mathematics–handed to them as basic facts, with no nuance. This turns learning math into a chore of routinely memorizing different formulas for another exam–a disadvantage to students who have worse memorization skills. In addition, these seemingly small disadvantages could be especially prevalent for students that suffer from anxiety. According to Thomas Armstrong, the Executive Director of the American Institute for Learning and Human Development and a 30-year expert in education, "[students with anxiety] can have difficulty finding a way into a problem, misread questions, or complete far fewer problems than they are capable of. [They] make careless mistakes because of the stress they are experiencing in the moment" (Armstrong). Not only is this system deficient, it hampers teachers' abilities to educate. Instead of being open to all levels of difficulty and complexity, teachers are expected to teach only one unit at a time, not accounting for the huge variability in both the skills of the students in the class and the styles of the teachers. Due to the rigid, inflexible system of mathematics education, many students, starting at young ages, are disadvantaged.

Furthermore, the importance and culture around standardized test scores and high marks continues to hurt students' education. An emphasis on a high score or a good grade is not effective for creating interest in math; it's effective for creating good test-takers. More and more students are taking advanced math classes in school because they are good at taking tests, not because they actually understand or care for the math. This molding of students and stifling of passion is exactly what hurts these students in the long run, leading to a lack of innovation in America. Even though standardized testing is generally a good measurement of math scores (not

necessarily English reading and comprehension skills), a culture built around it is not instructive and beneficial for the student. If a student doesn't score well on a standardized test, they feel a sense of shame, a sense of incompetence, instead of feelings of ambition and motivation on how much more they have to learn in math. Worse, what if a student scores well? Because they achieved their goal of obtaining a high score, that student is no longer motivated to learn more. What if that student didn't even understand math in the first place? According to Armstrong, these tests provide false senses of security: "If a student scores well on a test, then it is assumed that they know the material…this may not be true at all. The student may have simply memorized the fact or formula or trick necessary to do well on the test (some students are naturally gifted in taking standardized tests, others are not)" (Armstrong). Testing in classrooms is not that much better either. Students are studying for them like they are studying for their SATs and ACTs–redoing the same problems in order to just memorize and reuse instead of developing their own innovations and ideas about math. These tests occur in artificial environments, environments where there is rarely any collaboration, and forgetting commonplace knowledge can lead to consequences. In contrast, Mathematics used in real world applications–such as research or STEM-related careers– is about solving problems collaboratively and using already known principles and proofs that others have developed in order to solve real problems– there's no emphasis on rote memorization. In this sense, math education in America is not preparing students for the real world.

Throughout the last 4 years, the COVID-19 pandemic and its consequent quarantines and social isolations have resulted in the widespread adoption of online schooling: distanced, monotonous lessons that are essentially Powerpoint presentations through the format of Zoom instead of Youtube videos. Even though some have hailed online schooling as a new wave of instruction and the future of education, and while others have spoken outwardly against online schooling, the PISA and NAEP scores have still continued on the trend they were before: decreasing. People may be quick to blame it on the COVID-19 pandemic and online classes, but online schooling isn't the root of the problem: the problems brought on during online schooling are simply exacerbations of the problems that the deficiencies in traditional schooling have brought into students. The same teachers that were used to many years and even decades of traditional learning were expected to adapt and switch over to a completely different type of pedagogy: that of online education. The fact is, the ideals of traditional education still shine through the new format of Zoom meetings and Google Classroom. Online learning also disadvantages students without access to technology–in particular, underserved children of color. According to an analysis published by Alliance for Excellent Education, an organization dedicated towards justice and equality in modern day education, "One in three Black, Latino, and American Indian/Alaska Native families do not have high-speed home internet" (Ujifusa). The analysis goes on to state that students with lower internet speeds "spend more time on their homework, have lower grade point averages, and have weaker digital skills, even after controlling for socioeconomic factors that potentially influence academic performance", demonstrating the effects of a digital divide in the online education space (Ujifusa). Online

learning isn't the solution to solve the educational woes that many were hoping for– it has the same downsides as the methodologies in traditional education.

It's evident that there is a pressing need for a fresh approach to teaching methodology–considering all the flaws in modern day online and traditional education. The ideas and functions of a new concept come into play: Math Circles–informal educational programs and settings where students, typically from elementary to high school levels, engage in mathematical exploration and problem-solving outside of the traditional classroom environment. These circles are often led by high-level mathematicians and professors and aim to cultivate a deeper appreciation and understanding of mathematics in participants, in contrast to only learning math for the upcoming exam or the SAT and ACT.

Math Circles offer a new, unique, and refreshing solution to the current issues facing American mathematics education. Unlike conventional methods that often prioritize rote memorization and standardized testing, Math Circles continue to push the curiosity of their students, break new barriers in education, and provide a unique and enriching learning experience for students. They foster a sense of community and collaboration among participants, creating a supportive environment where students feel encouraged to share ideas and explore mathematical concepts together. This collaborative atmosphere helps build confidence and communication skills, essential for success in both academic and professional settings. Additionally, Math Circles emphasize problem-solving strategies and critical thinking skills, enabling students to develop a deeper understanding of fundamental mathematical principles. For example, students from as young as eight begin learning basic concepts of calculus. By presenting complicated and abstract ideas at a young age, Math Circles increase young children's exposure to advanced topics and better prepares them for the future. This approach not only enhances critical thinking skills but also cultivates a genuine passion for mathematics.

The existing Math Circles today also have a huge reputation of being affiliated with high levels of mathematical ingenuity–in line with the idea that many successful competitive math students learn through other means of education, not their American education systems. For example, many students from the Russian Math Circle have gone on to score highly in international mathematics olympiads and competitions around the world. The UCLA Math Circle, as well, also has such a reputation for its strength and ability in the competitive math realm. These Math Circles attract high level students that want to meet similar like minded students: in contrast to attending math classes as a requirement in schooling, they attend Math Circles as a means of true passion and curiosity. Similarly, when these ideas of Math Circles are applied to less competitive students, they would also feel a sense of inclusion and passion in contrast to simply studying for a grade in traditional schooling. In fact, even though it could be argued that Math Circles would only serve very advanced students, it has been shown that new, less competitive Math Circles have been inclusive and beneficial for many students, including underserved students of color (Long). The continued and expanded implementation of Math Circles from high level competitive groups in the United States to lower level, less competitive education would serve modern day United States Mathematics in many different ways.

The United States has been and is continuing to experience a tangible decline in math and educational standards–evident from the consistent drop in PISA and NAEP scores, key indicators of fundamental math skills. Extensive research suggests that embracing flipped, nontraditional classroom approaches and teaching styles, like Math Circles, collaborative and engaging spaces where math students can discuss mathematics and solve problems at their own pace, would rejuvenate the effectiveness of mathematics education. Moreover, these nontraditional classrooms often attract students who may not excel in traditional math settings, providing an inclusive space where everyone can thrive regardless of their background or ability level. Overall, Math Circles play a crucial role in enhancing education by promoting active learning, collaboration, and a genuine passion for mathematics.

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Does Money Buy Happiness and Fitness?: The Relationship Between Mental Health and Physical Activity Across Household Income Quintiles in Canada By: Arshiya Huq, Ayden Bravender, Kyna Sha, & Sehar Qureshi

Abstract

This study aims to examine the extent to which the relationship between physical activity (PA) and mental health across income quintiles in Canada. The concept of a social gradient is well-researched, yet there is not yet an analysis on the extent of discrepancies in health characteristics across the quintiles using data provided by Statistics Canada, from the Canadian Community Health Survey. We used this data and used RStudio to perform a Chi-squared test. The data was significant (p<0.001), and we visualised the data to examine the differences between quintiles. The differences in mental health characteristics and self-reported physical activity are concerning, and interventions are needed to identify positive ways to address these discrepancies on a large scale.

Introduction

Some say money buys happiness, but does money buy fitness too? Is there a connection between physical activity and mental health in relation to money? The answer to both questions is yes. In Canada, there is certainly awareness of mental health, yet considerable lack of access to mental health supports (Canadian Mental Health Association, 2023). An individual's socioeconomic status certainly plays a role in their ability to gain some support and be protected against having mental health issues in the first place. One such protection is physical activity (Smith & Merwin, 2020). The many benefits of physical activity are well known, such as lower risk of cardiovascular disease, stroke, hypertension, and high cholesterol levels (Nystoriak & Bhatnagar, 2018). PA has also demonstrated improvements for better sleep quality (Dolezal et al., 2017), increased energy and endurance, and ageing (Gopinath et al., 2018). PA also has a protective effect against mental illness. Much like mental health supports, the amount of physical activity a person can get is also dictated at least in part to socioeconomic factors. Since we know there are barriers, the question now becomes: how much of a discrepancy does socioeconomic status—specifically regarding income—create?

Physical activity (PA) is part of daily life, and contributes to every facet of health. The benefits are so varied because of the broad and multifaceted nature of PA. It's defined as any bodily movement produced by skeletal muscle and can be performed in a variety of domains, such as occupational, household chores, active travel, leisure-time, or family-related *(Mason, Curl, & Kearns, 2016)*. Generally speaking, any kind of movement could be included as PA. There are specific guidelines that various health organisations encourage. In Canada, adults are recommended to get an average of 150 minutes a week. For youth, Canadian guidelines recommend at least 60 minutes a day (Canadian 24-Hour Movement Guidelines, 2016).

There are many aspects to physical activity, such as social, psychological, and even financial health (Biawolski et al., 2021). All of these contribute to mental health. In fact, Engaging in regular periods of PA are linked with reduced anxiety, depression, self-image and cognitive function (Sharma et al., 2006). Physical activity can be a social activity to spend time with friends and deepen interpersonal bonds. It helps build a support network of friends and build self-esteem. Social activities and events through PA are ways to boost positive mental health. That being said, an individual's finances can also dictate what types of physical activity they are exposed to. For example, a wealthy individual has the funds to do more exclusive types of physical activity such as skydiving, horseback riding, or getting a membership at a gym. Outdoor PA is safer and more accessible, and is actually better than indoor PA for mental health (Gladwell et al., 2013). They have access to more recreational physical activity because of their socioeconomic status. Someone with a low socioeconomic status may not have access to a gym, or even have the time and energy to go for leisurely walks. All of this also plays a role in mental health. A lack of time and energy to invest in physical activity can mean fewer opportunities to socialise. PA has been shown to boost neurotransmitters such as endorphins, dopamine, and serotonin (Lin & Kuo, 2013). These hormones reduce anxiety and depression from poor mental health (Lin & Kuo, 2013), so people who are not able to meet physical activity guidelines don't get the rush of feel-good hormones. As a result, changes in the amount of PA individuals in lower socioeconomic statuses can affect mental health from many different angles (Sharma et al., 2006).

It is evident that PA, mental health, and socioeconomic status (SES) are related. As an individual's SES increases, positive health characteristics also increase. This relationship is called the social gradient of health (Bonaccio et al., 2020). There are a multitude of things that dictate a person's SES, such as education, occupation, wealth, ethnicity, and many more. Being in spaces where physical activity and positive mental health is the easy choice is something people in higher SES levels enjoy. People in lower SES groups may not have built-in nurturing environments, and many health behaviours are shaped by exposure. For example, it can come in the form of having a safe neighbourhood to play in, going to school with a well-funded physical activity program, having friends that are positive influences, and learning positive habits from parents. Not to mention, people with high SES are able to pay for and participate in a larger amount and more varied types of PA (Statistics Canada, 2021). These examples are things that are more likely to be seen in families with a high SES (Meyer et al., 2014). In fact, we see the effects of the social gradient in nearly every category of sport and PA in general across income levels (Statistics Canada, 2021). People with a higher income participate in PA more, and participate in more types of PA (Statistics Canada, 2021). Influences that shape exposure are in turn influenced by income; a family must have enough money to be able to afford and be surrounded by these things. A simple comparison is that expensive homes have more green space and walking trails, and are in high-income areas. Having a higher income will result in a higher SES, and more opportunities to improve PA and mental health. Low income areas are usually less safe, have poorer education, and overall fewer resources which are all linked to poorer

mental health (Anxiety & Depression Association of America, n.d.). A lot of the discrepancies boil down to income, therefore we will be using household income quintiles to represent different SES groups.

The literature has made it clear that mental health and physical activity are related to household income. However, quantifying the differences between income quintiles can inform the depth of disparities in mental health resources and amount of PA. We hypothesise that mental health and physical activity will be drastically different between the highest and lowest income quintiles, and we will examine the true extent of how much the relationship changes between income quintiles in regards to PA and mental health in this study.

Methods

The data was collected from Statistics Canada's compilation of the results of the Canadian Community Health Survey (CCHS). The survey was a cross-sectional survey that received responses from all provinces of Canada, and the data was voluntarily provided by the participants. The collection of data we used took place between January 2021 and February 2022 excluding May, to avoid interfering with the census collection. The variables isolated were Income Quintiles (a measure of SES), perceived mental health (MH), and self-reported physical activity (PA). There were five income quintiles, with quintile one (Q1) representing the 20% of Canadians with the lowest annual household income and quintile five (Q5) representing the 20% with the highest. There were two categories for perceived mental health: very good or excellent and fair or poor. Physical activity was measured separately for adults (18 and older) and youth (aged 12-17). Adults reported whether or not they received more than 150 minutes of exercise every week and youth reported whether or not they exercised an average of 60 minutes per day.

Chi-squared tests were first conducted with the built-in function in RStudio to check the significance of the data. The first chi-squared test was done with a contingency table including all of the variables, the second test was done with a contingency table including SES and MH, the third test was done with a contingency table including SES and PA ($p<0.001$), and found the data to be significant. Chi-squared post-hoc tests were then conducted using an imported function, using the Bonferroni method of value adjustment. The post-hocs conducted compared SES with each indicator, as well as SES and all the indicators ($p<0.001$).

Results

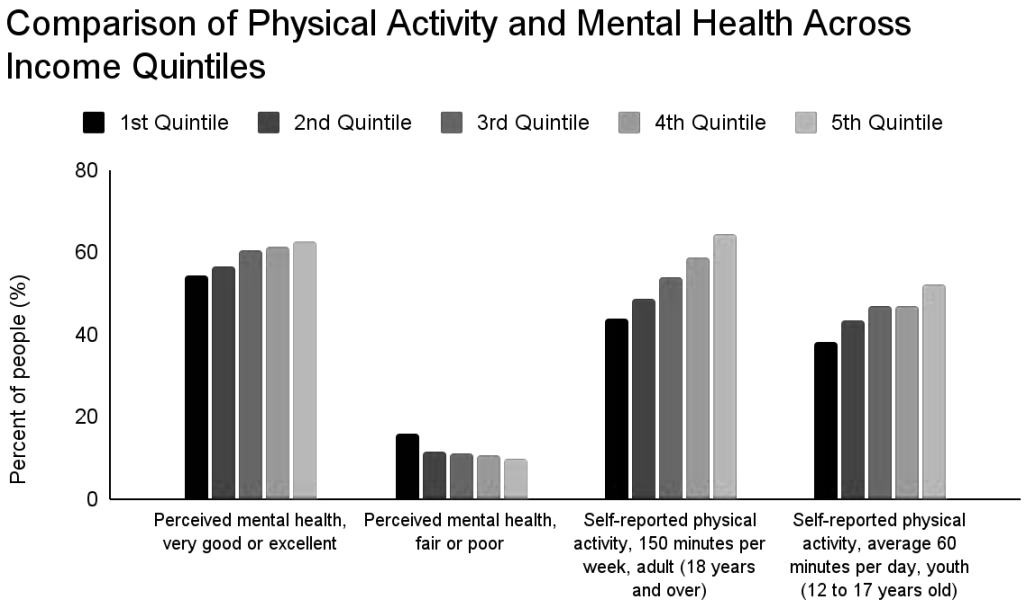

Figure 1.1 Mental health and physical activity variables to income quintiles. Perceived good mental health and self-reported physical activity in both age ranges are positively related to higher income, and perceived poor mental health is negatively related to higher income.

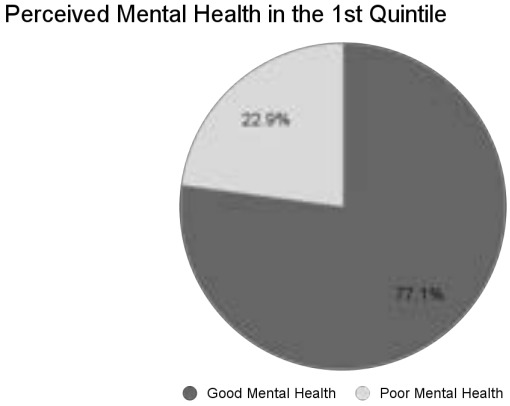

Figure 1.2 Perceived very good or excellent mental health with perceived fair or poor mental health within Q1.

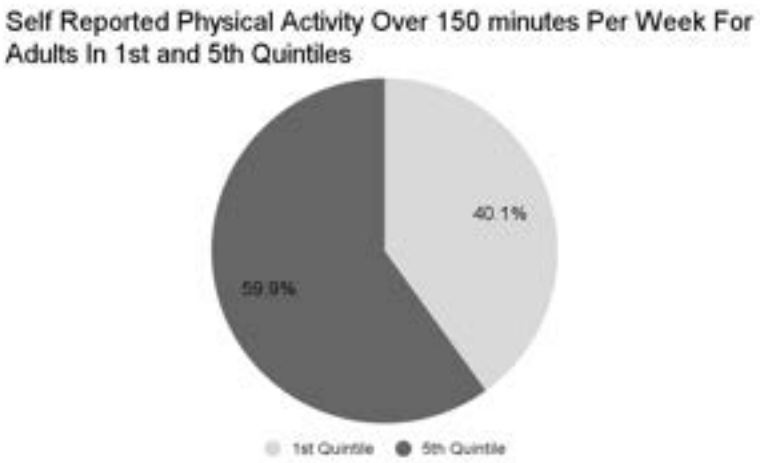

Figure 1.3 Self reported physical activity over 150+ minutes per week in adults in Q1 and Q5.

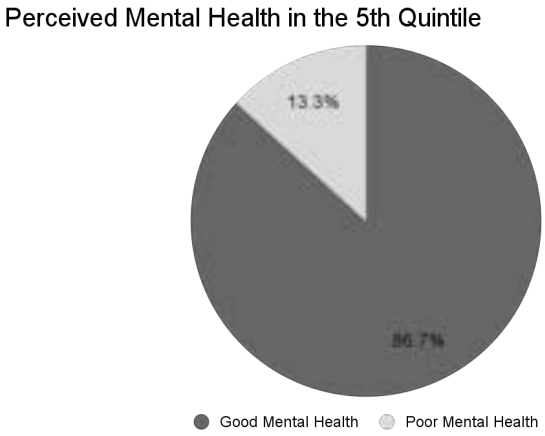

Figure 1.4 Comparing perceived good mental health to perceived poor mental health of people in Q5.

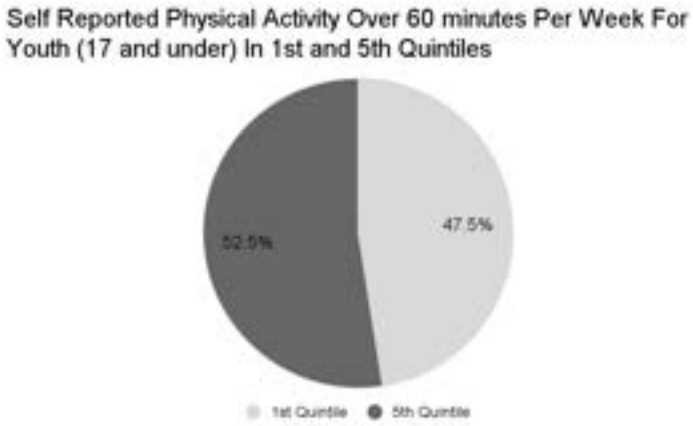

Figure 1.5 Comparing self reported 60+ minutes of physical activity per week in youth (ages 12 to 17) in Q1 and Q5.

Table 2.1 Health characteristics related to mental health and physical activity reported by income quintile

Health Characteristic	Q1 (%)	Q2 (%)	Q3 (%)	Q4 (%)	Q5 (%)
Perceived mental health, very good or excellent	54.2	56.4	60.6	61.2	62.7
Perceived mental health, fair or poor	16.1	11.6	11.0	10.6	9.6
Self-reported physical activity, 150 mins/week (18+ years old)	43.9	48.6	53.7	58.8	64.3
Self-reported physical activity, average 60 mins/day (12-17 years old)	38.2	43.3	46.9	47.0	52.0

Discussion

The data supports the idea of the social gradient, as there is a clear upward trend of all positive health indicators and downward trend of all negative health indicators as income

quintiles increases. There are significant differences between each income quintile in every category, so the data continues to uphold the idea of a social gradient. The raw numbers themselves are concerning; despite the improvement in perceived mental health as income increases, the increase itself is very small. As for PA, the differences between income quintiles are more drastic. It is also important to state that it's easier to quantify how much PA individuals are getting, as opposed to mental health reports. All of the data used in this study is self-reported, yet social desirability bias still exists

To start with the mental health disparity, 54.2% of people in the lowest income quintile in the representative sample claim to have good mental health. There is a modest increase with higher income quintiles. Only 62.7% of people from Q5 have perceived very good or excellent mental health. The glaring issue that comes to light with this data is that a little more than half the population has good perceived mental health. With the lack of access to mental health resources and morbidities associated with poor mental health, the country must make more resources available. Especially in low-income areas where there are fewer resources in general, interventions should be focused there. If someone from a higher income quintile has poor mental health, they have more access to healthcare and a larger variety of support. However in lower income quintiles, that support seems out of reach. According to this data, 16% of people from Q1 have fair or poor mental health. Initiativesfocused on problems that specifically affect low-income communities can reduce this number, and should be a focus of the Canadian healthcare system. In fact, Q5 is quite low compared to the other quintiles. Q2 to Q5 decrease by approximately 1%, yet the difference between Q1 and Q2 is much higher at about a 5% difference.

As for physical health, the increases in PA are larger than the difference in mental health between income quintiles. This may exist because some forms of sport and physical activity are more expensive, such as horseback riding or sports that require lots of commitment and high-cost equipment. People in higher income quintiles have more access to those means of PA. According to Statistics Canada data on Participation in Outdoor Activities by Household Income (2021), participation in every category consistently increases by income quintiles. More adults are meeting the recommendations than children, and that may be because of independence and the increase in screen time in adolescents during the COVID-19 lockdown. A study found that adults' PA stayed the same during the pandemic, but children increased sedentary behaviour and screen time (Watt & Colley, 2021). With nothing to do in the house and online school, sedentary time is taking more time out of the day. This finding may tie into income disparities as well, because parents in low income households may have even less time and energy to spend with kids after long days of work and job insecurity during the pandemic. Many parents tend to turn to screens as a babysitter for adolescents to occupy them while parents get some rest.

The 3rd and 4th quintiles showed quite similar percentages with the perceived mental health statuses and self-reported physical activity with youth (12-17 years old). This is likely to the similar lifestyles they both have as they can be perceived as "middle class" to many. Their difference in wealth is likely related enough to acquire similar opportunities such as investing in

gym memberships, sports clubs, mental health resources, and transportation affordability — with both categories having the financial means to show a significant percentage of good mental health and PA but ultimately not the highest. Furthermore, the 5th quintile, are the upper wealthier individuals that are incentivized to lead prosperous lives and hold the status of having the most PA and very good or excellent perceived mental health. This is probable because of their financial comfort and mobility towards prioritising PA, as they would have very little to no barriers that would inhibit their ability to involve themselves in fitness. These groups live lush lives and would take the statistics of having higher PA automatically correlated to having better mental health.

Access to different types of PA can range within the cost of being physically active regularly, the proximity to spaces, and to environments where it's safe to engage in PA. Within lower household incomes (quintiles 1 or 2), there is a greater difference in percentages when it comes to equipment-based outdoor activity compared to simply walking or jogging. People in higher quintiles (4 or 5) have more participation in activities such as jogging, running, rollerblading, cross-country running, bicycling, boating, surfing, etc. compared to lower-income households. Overall, the highest categories in activity for lower quintiles were shown in walking, hiking, going to the park, and bicycling compared to the more expensive and equipment-based outdoor activities. This is likely because of easier proximity to safer public spaces to engage in PA and the cost being less. With the more equipment-based PA (skiing, snowboarding, mountain climbing, golfing, croquet, kayaking), there is a greater percentage for the higher household incomes with little to no real data being reported for lower-income households. This is expected due to the better financial security the higher quintiles possess opposing the lower quintiles.

There are consequences of poor physical health and mental health as previously discussed, and lower income quintiles don't have the resources to improve their mental health or amount of physical activity. However those consequences can eventually emerge as cardiovascular disease or extreme depression. There are millions of people in Canada that fit into lower income quintiles, and many of them are stuck between a rock and a hard place. They are at a higher risk of morbidities, many of which are preventable. There needs to be a shift so that physical activity and mental health resources are easy to access and easy choices to make. One of the big advantages that higher income quintiles enjoy regarding this topic is that they don't need to be as purposeful in making mental health and physical health choices, the positive choices are easy. Bringing the implicit PA and mental health opportunities and support to lower income quintiles may alleviate some of the disparity. By preventing mental health issues and physical morbidity in the first place, we can see a broad, cultural shift in health outcomes where the whole population benefits, and the disparities between high income quintiles and low income quintiles decrease.

With that said, long-term health can be significantly affected if financial barriers emerge for people striving to involve themselves in PA and in boosting their wellness. Individuals without enough capability to afford the amenities of PA would likely have negative consequences overtake them in the long run — moreover, neglecting regular PA could result in

more health concerns compared to one implementing proper fitness in their lives. This financial issue could be curbed with municipal governments and communities creating open-access green spaces that are available and safe for the public. Additionally, communities that create free or low-cost programs would be effective in offering an attainable opportunity for lower-income households to participate in PA without any costs inhibiting their ability to do so. Subsidies provided by the city/community that offer transportation toward recreational facilities at a lower cost are also an option that would increase the number of low-income groups' involvement in PA. Ultimately, these examples would progress and improve people working towards becoming more physically active and mentally healthier.

Limitations and Future Directions

In this paper, we used graphs and pie charts to illustrate the difference in PA and mental health variables in the different income quintiles, however they were all in separate graphs. Putting all these variables in a single model may be more useful for visualisation and analysis purposes.

Our study only used 3 variables, however socioeconomic structures are much more complicated. For future studies, it would be beneficial to see a more holistic view of socioeconomic status compared to PA and mental health instead of just using income. Looking at how the level of education or attitudes around PA during youth could provide valuable insight on changing the current disparity we see in low-income neighbourhoods.

Another weakness of this study is that we couldn't provide evidence from a study that would directly support the claim that mental health and physical activity outcomes would be improved by implementing changes to the built environment. We inferred that these improvements would occur because many high-income areas with better mental health have green spaces and other resources that contribute to positive health characteristics.

In the future, civil engineers and urban designers should create schools, communities, and workplaces with PA and mental health considerations in mind. This is especially imperative for low-income areas, as they have the lowest percentage for overall perceived mental health and PA. Since many people in those areas have barriers preventing them from actively getting support, positive influences on PA and mental health should be built into the environment. Environmental features like open green spaces, walkways, safe parks, community centres, and community initiatives should be readily available so people who need the support have the help they need for long-term health.

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Buy a Flashlight: Money is Getting Darker By Kai Thoma

Abstract

Dark money is taking over. Special interests hide behind nonprofit organizations to donate to politicians. Within this secret feed of money, anyone has the ability to influence elections. Special interest groups can use an elected official as a vessel to cast their own political views and lean toward their preferred policies. Some that wish to shade the people's views do not see an issue with dark money; however, civilians must see who is behind political advertisements. Transparency of dark money used in American politics is essential.

Working the System

Dark money is a primary source of political corruption. Nonprofit organizations can funnel unlimited amounts of money toward political activities with the transactions closed to the public eye (Irvin). The financial processes of anonymous donors have coined this term. Dark money raises threats to political campaigns, voters, and the welfare of the United States government. The nonprofit organization Freedom Frontier reportedly spent 5.9 million dollars in 2016. Approximately 75% of the money was spent on political activities (Irvin). With institutions spending the majority of their profits on political campaigns, questions are raised considering the ethics of dark money. Voters are swayed by the real ambition behind these nonprofits that insist on hiding donors. Attempts were put in motion to limit the campaign spending of a singular individual. The Federal Election Campaign Act of 1971 was created to instill disclosure requirements on federal political campaigns (Dimmery and Peterson). However, organizations attempt to avoid transparency laws, and with the introduction of Citizens United, dark money remains in the shadows.

Citizens United

The case Citizens United v FEC eliminated donor transparency. The case ruled that donors can anonymously spend unlimited amounts of money on electioneering. The organizations have free reign to spend their profits on political advertisements (Beckel). These advertisements express strong biases targeting candidates. Corruption is at stake when politicians are funded by donors hidden from the public. These sources are unknown and therefore unreliable. Civilians must have access to those who are responsible for influencing their political views. Despite popular opposition, Justice Anthony Kennedy supported Citizens United due to the belief that limiting political spending would be a violation of the First Amendment right (Gerken). The Supreme Court ruled that dark money and the organizations abusing it are equivalent to a person exercising their freedom of speech. The groups pouring millions into elections do not have the intent of merely sharing their views. They aspire to cast non-factual propaganda for political gain. The verdict of Citizens United supported an overflow of dark money usage that is nearly impossible to regulate. Currently, a range of wealthy interests secretly support candidates with newfound donor nondisclosure. The issue progresses as anyone could be influencing impressionable voters.

Dark Money Groups

Wealthy interests can hide their political spending through dark money groups. Dark money seeps into elections by way of anonymous donations through 501(c)(4), social welfare groups, or 501(c)(6), trade associations (Dewan). These groups are not required to reveal their donors. They can actively participate in political funding by making contributions to Super PACs, groups deemed unregulated by how much they are allowed to spend on political campaigns. Super PACs are forced to disclose donors unless they receive a contribution from a social welfare group or trade association (Dewan). The individual behind the donation in this case is still masked. The public must know the true source of the information they are receiving. 501(c)(4) groups have reportedly spent 763 million dollars in political contributions to nonprofit organizations over an eight-year period. The U.S. Chamber of Commerce and Planned Parenthood Action Fund Inc. is responsible for over half of the contribution since the Citizens United decision in 2010 (Willis). The wealthy avoid disclosing their political views and can corrupt the administration through the massive amounts of funds they inject into elections. The government must put an end to the possibility that affluent groups are rigging the political system in their favor. The only way to reduce this corruption is to project transparency on the independent donors of nonprofits.

Foreign Exploitation

With political donors hiding in the dark, foreign exploiters can abuse the system to gain power in the US democracy. Foreigners are prohibited from spending in US elections. Citizens United opened doors for foreign corporations to anonymously hold power in election spending. Nonprofits currently can hide illegal foreign donations. The social welfare organization, NRA, spent 54 million dollars in the 2016 election. Around 31 million dollars was spent towards Donald Trump's election, doubling the amount the NRA spent during the previous election (Torres-Spelliscy). No explanation of where the NRA accumulated these funds was found. Inquiries about possible foreign relations with the NRA were publicized and the FBI investigated whether a Russian banker had ties with the NRA (Torres-Spelliscy). Donor opaqueness warrants the possibility of foreign money leaking into elections. New laws must be passed to ensure voter transparency. Political nonprofits should disclose their financial bankers to eliminate the chance of foreign corruption.

Dark Money Advertisements

Nonprofit organizations can secretly fund political advertisements that influence voters. If a group spends an overwhelming amount of money on a campaign advertisement, then they must report the donors who contributed to buying the ad. However, only ads that call for the election or "express advocacy" must be disclosed (Briffault). This means that advertisements can belittle candidates as long as they do not explicitly tell citizens how to vote. In this case, the people buying the ads would still be hidden. Non-political organizations become involved in advertising

indirectly. The groups donate to another organization that is responsible for buying the ad. This makes the source of the advertisements nearly impossible to trace, only listing the many organizations involved in the chain (Briffault). Anyone could be influencing the public. Advertisements are untrustworthy unless there is donor nondisclosure. If organizations are going through such trouble covering their tracks, the information must be unreliable. If voters know there is dark money in elections, they become skeptical of every political advertisement, even those that are neutral (Schnakenberg, et al.). Voters are harmed in this process since they can no longer access trustworthy sources. Millions of dollars continuously fall under the spending of propaganda. America is letting citizens blindly follow the media without acknowledging the source of the information.

Corruption

Large sums of dark money influence policy makers and corrupt the system. Education interest groups spent over 2 billion dollars lobbying Congress between the years 1998 and 2017 (Baser). Specifically, Alabama's higher education institutions internally lobby with dark money. The Alabama Association for Higher Education pressures policy makers to sway decisions in their favor (Baser). Universities use the impact of money to advance their institution's personal goals. Congress will feel indebted to these donors, keeping the politician under the thumb of the organizations. On a larger scale, any person hiding behind an organization has the power to influence elected officials. State representatives should be voting in the interest of their constituents; however, special interest groups can sway the government representative. This takes power away from voters.

Conclusion

Dark money is a threat to American democracy. Not knowing the motivation or agenda behind dark money donors is dangerous to the government. Movements with the purpose of unveiling dark money's donors must activate. Dark money brings curiosity as to why organizations go through immense trouble to hide their donors. There are more questions than answers regarding the coverup of massive funds used to manipulate U.S. elections. Americans may never have truth in government until there is transparency on dark money.

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China's Hybrid Economic Model and Its Global Implications By Tarang Chavali

Abstract

China's economic landscape is a fascinating amalgamation of socialist principles and capitalist practices, challenging conventional categorizations of economic systems. Over the past four decades, China has undergone a transformative journey, transitioning from a Maoist regime to a hybrid model characterized by a unique blend of state-led initiatives and market-oriented reforms. This evolution has resulted in outcomes typically associated with capitalism, including rapid economic growth, technological advancement, and increased productivity. However, China's economic model remains distinct from both pure socialist and capitalist systems, reflecting a pragmatic integration of socialist ideals with capitalist mechanisms. The intricate interplay between socialist aspirations and capitalist realities in China's economic development sheds light on the country's adaptive approach and its implications for global economics.

China has leveraged market-oriented reforms to stimulate economic growth, foster innovation, and attract foreign investment. This pragmatic approach has enabled China to navigate complex global economic dynamics while retaining significant state control over key sectors of the economy. Investments in public goods provision and infrastructure development have underscored the government's commitment to enhancing collective well-being and promoting inclusive growth. However, challenges persist, particularly in addressing environmental degradation and mitigating the adverse effects of rapid industrialization and urbanization. The complexities of China's hybrid economic model offer insights into its resilience, challenges, and future prospects amidst a rapidly changing global economic landscape.

Introduction

China's economic landscape is a captivating amalgamation of socialist principles and capitalist practices, challenging conventional categorizations of economic systems. Over the past four decades, the country has embarked on a transformative journey, transitioning from a Maoist regime to a hybrid model characterized by a unique blend of state-led initiatives and market-oriented reforms.[1] This evolution has led to outcomes typically associated with capitalism, such as rapid economic growth, technological advancement, and increased productivity.[2] However, China's economic model remains distinct from both pure socialist and capitalist systems, reflecting a pragmatic integration of socialist ideals with capitalist mechanisms. This essay aims to explore the intricate interplay between socialist aspirations and capitalist realities in China's economic development, shedding light on the country's adaptive approach and its implications for global economics.

[1] Naughton, Barry. "Is China Socialist?" *Journal of Economic Perspectives* 31, no. 1 (2017): 3-24.
[2] Kornai, Janos. "What the Change of System From Socialism to Capitalism Does and Does Not Mean." *Journal of Economic Perspectives* 14, no. 1 (2000): 27-42.

China's economic trajectory represents a paradigm shift in traditional economic thinking, challenging the dichotomy between socialism and capitalism. By embracing elements of both systems, China has forged a unique path toward prosperity, resilience, and global leadership.[3] While officially maintaining its socialist identity, the country has leveraged market-oriented reforms to stimulate economic growth, foster innovation, and attract foreign investment.[4] This pragmatic approach has enabled China to navigate complex global economic dynamics while retaining significant state control over key sectors of the economy.

One of the hallmarks of China's economic model is its emphasis on public goods provision and infrastructure development. Extensive investments in high-speed rail, highways, and urban development projects underscore the government's commitment to enhancing collective well-being and promoting inclusive growth. These initiatives have not only improved connectivity and mobility but have also stimulated regional economic development across the country. However, challenges persist, particularly in addressing environmental degradation and mitigating the adverse effects of rapid industrialization and urbanization.[5]

China is socialist, although it has changed over time. The country combines a socialist political and economic perspective. It has seen rapid economic and productivity growth as well as technological development, much like we would expect under capitalism. China's state-led projects include infrastructure development and an emphasis on redistribution and equality, such as caring for the poor. [6]

China has seen outcomes that we might expect only under capitalism by embedding capitalist characteristics in a socialist economic and political system. Their incorporation has resulted in economic growth, productivity growth, and technological advancement. However, China has still maintained strict control over their economic system, resulting in a hybrid economic system that is different from other socialist countries such as Cuba and the former Soviet Union.[7]

Capitalism and Socialism

Scholars argue capitalism has unique characteristics that lead to technological innovation and economic growth. Within capitalism, firms have a profit motive and they compete for competitive advantage. Competition between firms requires firms to use their resources effectively, making it necessary for firms to find the most efficient ways to do things. This leads them to be efficient, especially in terms of resource allocation, and to innovate so they can compete. The combination of these characteristics leads to economy-wide innovation, productivity, and ultimately economic growth.[8]

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[3] Naughton, "Is China Socialist?"
[4] Hsueh, Roselyn. "State Capitalism, Chinese-Style: Strategic Value of Sectors, Sectoral Characteristics, and Globalization." *Governance: An International Journal of Policy, Administration, and Institutions* 29, no. 1 (2016): 85-102.
[5] Naughton, "Is China Socialist?"
[6] Kornai, "Change of System," 38.
[7] Naughton, "Is China Socialist?"
[8] Kroeber, Arthur R. China's Economy: What Everyone Needs to Know. Oxford: Oxford University Press, 2000.

Competition and the profit motive are two related driving forces within capitalist economies. In capitalist systems, businesses exist with the primary goal of making profits, necessitating continuous innovation and improvement. Competition among businesses further amplifies this drive, as companies vie for market share and seek a competitive edge. [9]

Businesses operating in a competitive market are compelled to optimize their processes, ensuring the most effective use of resources. Businesses strive to minimize costs and maximize output, leading to a more effective use of resources. This efficiency extends to both human capital and natural resources, ensuring that production processes are streamlined and outputs are of high quality.[10] If a firm does not operate efficiently in a market with low barriers to entry, a new and more efficient firm can enter and outcompete the original firm. This dynamic interplay between the profit motive and competition creates an environment where technological progress is not only encouraged but becomes integral to the survival and success of businesses.[11]

The emphasis on efficiency within capitalist systems not only boosts productivity but also serves as a driving force for technological advancement. In capitalism, firms are incentivized to innovate in order to gain a competitive edge over their rivals. Moreover, the legal framework within capitalist economies encourages investment in research and development, fostering a culture of innovation and competition.[12]

Furthermore, capitalism's dedication to optimizing resource allocation creates a fertile ground for technological progress, essential for sustainable economic growth. Endogenous growth theories underscore the pivotal role of knowledge and technological advancement in driving economic growth. These models argue that innovation not only enhances productivity directly but also generates positive spillover effects, fueling further innovation and fostering continuous economic expansion. In essence, innovation begets more innovation, leading to a cycle of growth within capitalist economies.[13]

Kornai argues that socialist countries grow slower because they are less focused on innovation, while capitalist countries are more focused on competition and technological advancement.[14] Lenin, a socialist leader, has acknowledged that capitalism is good at making a country's economy more productive. It is argued that capitalism's traits make it a stronger force for quick and continuous technological progress rather than socialism.[15]

Kornai also argues that capitalism encourages innovation, uses resources effectively, and has a track record of promoting higher productivity when compared to socialist systems.[16] When juxtaposed with socialist systems, where central planning often hampers efficient resource

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[9] Kroeber, "What Everyone Needs to Know,"
[10] Naughton, "Is China Socialist?"
[11] Hu and Khan, "Economic Issues 8 -- Why Is China Growing So Fast?" n.d. International Monetary Fund. Accessed March 21, 2024. https://www.imf.org/external/pubs/ft/issues8/index.htm.
[12]Joffe, Michael. "The Root Cause of Economic Growth under Capitalism." Cambridge Journal of Economics, vol. 35, no. 5, 2011, pp. 873-96. http://www.jstor.org/stable/24232428.
[13]Liberto, Daniel. "Endogenous Growth Theory: Definition, History, and Criticism." Investopedia. Accessed 7 Apr. 2024. https://www.investopedia.com/terms/e/endogenousgrowththeory.asp.
[14] Kornai, "Change of System," 38.
[15] Kornai, "Change of System," 38.
[16] Kornai, "Change of System." 38.

allocation, capitalism showcases its strength. The flexibility of markets in responding to supply and demand dynamics allows for a more agile and adaptable use of resources, resulting in economic efficiency. Even socialist leaders, such as Lenin, have acknowledged the efficacy of capitalism in driving productivity and technological progress. This recognition underscores the inherent strengths of capitalism in achieving rapid and continuous economic advancements.

Empirical evidence indicates that countries adhering to capitalist principles tend to experience sustained economic growth [17]and increased worker productivity. Capitalism's emphasis on competition and meritocracy encourages businesses to operate more efficiently, leading to higher productivity levels among the workforce. Capitalism's profit-driven nature and relentless pursuit of advanced technology contribute to accelerated economic development. The division between East and West Germany during the Cold War serves as a compelling illustration. While West Germany embraced a capitalist model, East Germany adhered to socialism. The subsequent economic disparity between the two regions emphasized the superior productivity and economic growth achieved under capitalism.[18, 19]

China's Economic System

China's economic identity, officially labeled as socialist, has undergone a transformative journey over the past four decades. The government's substantial control over income streams, evidenced by its influence on fiscal revenues, social insurance premiums, land revenues, and state-owned enterprise profits, reflects a marked capacity to shape economic outcomes. In terms of asset ownership, China has evolved from a predominantly state-owned economy to a diversified landscape, with private and foreign-owned firms dominating many sectors. However, critical industries such as resources, utilities, and finance remain under significant government control. Notably, the government's net assets, including land, public service units, state-owned enterprises, and financial entities, are nearly one-and-a-half times the country's GDP.[20]

China has experienced outcomes that economists claim are only possible under capitalism: technological advancement, higher productivity, more efficient economic growth. However, China identifies as socialist and maintains many socialist characteristics. They have state-owned enterprises, a planned economy, government control and ownership, and strict macroeconomic regulations. How might China also see outcomes associated with capitalism? China also has developed and integrated economic factors that are seen as capitalist, including entrepreneurship, private ownership, and integrated international trade. Although these factors are capitalist in their form, they are integrated with Chinese socialist ideology. Thus, China has managed to achieve rapid growth in productivity, income, and technology by embedding particular capitalist characteristics in a socialist system.[21]

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[17] Kornai, "Change of System," 38.
[18] Kornai, "Change of System," 38.
[19] Hsueh, Roselyn. "State Capitalism, Chinese-Style."
[20] Kroeber, "What Everyone Needs to Know."
[21] Kroeber, "What Everyone Needs to Know."

The question of whether China is socialist today is explored through the lens of four descriptive characteristics: capacity, intention, redistribution, and responsiveness. In terms of intention, a socialist government aims to shape economic outcomes distinct from a non-interventionist market. China, despite embracing market-oriented reforms, maintains a socialist identity and emphasizes state ownership as the "leading force."[22] On the redistribution front, socialist policies are expected to benefit the less well-off citizens. China's pursuit of inclusive growth and pro-poor policies aligns with this socialist objective. Additionally, responsiveness to the population's changing preferences is considered a socialist trait, demanding some mechanism for public influence on economic and social policies. While the Chinese Communist Party remains in power, the examination of responsiveness requires ongoing scrutiny.[23]

The evolution of China's government control and ownership is reflected in its macro-economic regulations. Over the last two decades, the government's influence has expanded significantly, particularly in controlling income streams. Government assets, including land, public service units, state-owned enterprises, and financial institutions, contribute to substantial control, reaching 38 percent of GDP in 2015.[24] The relaxation of ownership restrictions has allowed the government to reap the benefits of competition and create a more efficient economy. Despite not owning the means of production in the traditional socialist sense, China's government maintains significant ownership positions, especially in strategic sectors. The ability to transform ownership into income streams signifies a qualitative change, positioning the government with wealth and capacity to intervene assertively in the economy. [25]

China's management of its exchange rate is emblematic of the extensive control the government exercises over its economy. By maintaining a managed float system, China can influence the value of its currency, the yuan, relative to other currencies, allowing it to support its export-oriented industries and maintain competitiveness in global markets. This control over the exchange rate serves as an example of the type of centralized economic management prevalent in China. Moreover, fiscal reforms aimed at centralizing power and imposing discipline on local governments further underscore the government's overarching goal of strengthening its control over economic policies and resource allocation. These reforms, while intending to enhance economic stability and shift development priorities towards consumer-oriented sectors, highlight the government's proactive role in shaping the country's economic landscape.[26]

State-Owned Enterprises (SOEs) and private enterprises play distinct roles in China's economy. SOEs are instrumental in the government's macroeconomic management, resource allocation, and infrastructure development. However, the private sector has been the primary driver of China's sustained high growth rates over the past three decades. Most of the gains in employment and productivity since 1978 can be attributed to the reallocation of resources from

[22] Kroeber, “What Everyone Needs to Know.”
[23] Hu and Khan, “Economic Issues 8.”
[24] Naughton, “Is China Socialist?”
[25] Hu and Khan, “Economic Issues 8.”
[26] Hu and Khan, “Economic Issues 8.”

the state to the private sector. Today, the private sector accounts for the majority of economic activity, including about 85 percent of employment, two-thirds of GDP and fixed investment, half of exports, and more than half of the trade surplus. Despite its significant contributions to the economy, the private sector faces challenges, including fragmentation and political weakness, while SOEs maintain substantial political influence and control over resources, disproportionate to their economic performance. [27]

China's economic model has prompted discussions regarding its socialist or capitalist nature, reflecting its unique blend of ideologies and practices. While officially identifying as socialist, China has integrated several capitalist characteristics into its economic system. This integration has facilitated rapid growth in productivity, income, and technology, challenging conventional notions of economic categorization.[28] However, the extent to which China embodies socialist ideals remains a subject of debate. Analyzing four descriptive characteristics—capacity, intention, redistribution, and responsiveness—provides insights into China's socialist orientation. Despite embracing market-oriented reforms, China emphasizes state ownership and intervention, aligning with socialist objectives of shaping economic outcomes and promoting inclusive growth. Furthermore, the government's proactive role in economic management, reflected in extensive control over income streams and macroeconomic regulations, underscores its socialist orientation. However, ongoing scrutiny is necessary to assess the responsiveness of China's policies to the population's changing preferences, a key aspect of socialist governance.[29]

The Evolution of China's Economic System

The evolution of the private sector in China can be observed in three distinct phases. Initially, from the late 1970s to the mid-1990s, private economic activity expanded rapidly, albeit with insecure legal foundations and dominance by individual business enterprises. The second phase, from the mid-1990s to 2008, saw significant strengthening of private property rights and reduced state intervention, leading to substantial growth in private output and employment. However, since 2008, there has been a perception of the state advancing at the expense of the private sector, evidenced by increased government intervention, particularly in favor of SOEs. While the private sector continues to outperform SOEs in terms of efficiency and profitability, sustained economic growth in China will depend on reforms that enhance enterprise efficiency, including further opening up service industries to private competition and exerting stronger financial discipline on state enterprises.[30]

One key reason for the rapid economic growth of China is their industrial policy, which resulted in investments in manufacturing and exports. Becoming a leader in manufacturing and

[27] Kroeber, "What Everyone Needs to Know."
[28] Kroeber, "What Everyone Needs to Know."
[29] Kornai, "Change of System," 38.
[30] Kroeber, "What Everyone Needs to Know."

exports supercharged their economy. The Chinese government maintains strict controls over their industrial policy, which is not typically seen in capitalist countries. [31]

China's approach to exports underwent significant changes under Deng Xiaoping's leadership in the late 1970s. At that time, China shifted its focus from capital-intensive heavy industries to labor-intensive light manufacturing, like clothing and electronics. This change was aimed at utilizing China's abundant cheap labor. Additionally, policies were put in place to encourage the export of these light industrial goods to earn foreign currency, allowing China to import capital equipment needed for further development. These reforms led to impressive growth, with exports increasing sixfold between 1978 and 1990, helping China establish itself as a major player in the global economy.[32]

Under Jiang Zemin and Zhu Rongji in the 1990s, China intensified efforts to attract foreign investment and promote export-oriented industries. Foreign direct investment (FDI) skyrocketed, peaking at $45 billion in 1997, and a significant portion of this investment went into export manufacturing. By the end of the decade, more than half of China's exports were produced by foreign firms. However, under Hu Jintao's administration in the 2000s, industrial policy took on a more statist approach, focusing on consolidating state-owned enterprises (SOEs) and promoting large-scale infrastructure projects. Despite this shift, exports continued to grow rapidly, driven by favorable global conditions and China's entry into the World Trade Organization (WTO).[33] While government policy evolved over the years, exports remained a crucial component of China's economic strategy, contributing significantly to its rapid growth and global economic influence.[34]

Between 1980 and 2010, China experienced a huge increase in its productivity and economic growth. This happened because the government's plans and the incentives for officials to perform well worked together. The official plans set goals for economic growth that focused on sustainability and environmental friendliness. However, the incentives for officials encouraged even faster growth. After 2010, things changed. The government, under Xi Jinping, started caring less about just economic growth and more about other things like reducing debt, helping the poor, and protecting the environment. This shift happened just as China's ability to grow quickly was slowing down. So, even though the government became more involved in the economy, it was happening at a time when rapid growth was becoming harder to achieve. This shows how China's economic strategies are changing over time, influenced by both socialist ideals and the practical need for economic success.[35]

China's economic evolution, particularly during the high-speed growth era from approximately 1980 to 2010, was characterized by a complementary relationship between the highly incentivized bureaucratic environment and official plans. The bureaucratic incentive

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[31]Pike, Lili. "How Green is China's High-Speed Rail?" China Dialogue. Accessed 21 Mar. 2024. https://chinadialogue.net/en/energy/11174-how-green-is-china-s-high-speed-rail/.
[32]Lubin, David. "China's 'Renminbi Trap': The Economy Needs a Weaker Currency, but Beijing is Unable to Act."
[33] Pike, "China's high-speed rail."
[34] Lubin "China's 'renminbi trap.'"
[35] Kroeber, "What Everyone Needs to Know."

system incentivized broad-based investment, and the five-year plans targeted sustainable, balanced, and environmentally friendly growth. However, since 2010, China's growth dynamics have shifted, and the Xi Jinping administration has introduced new indicators beyond economic growth, indicating a changing relationship. The recent 13th Five-Year Plan aims for high-speed growth, creating a paradox as administrative interventions increase while growth potential slows. [36]

China's economic growth, exemplified by its "miracle growth" era, has been marked by a focus on development and poverty reduction. The government actively intervened in poverty-stricken regions through targeted policies and fiscal transfers for local development.[37] However, income inequality increased during this period, indicating limitations in distribution efforts. The country's approach to poverty alleviation primarily centered on fostering local economic growth, aligning with the bureaucratic incentive system. [38]

China's focus on physical infrastructure, exemplified by extensive high-speed rail and highway networks, reflects a massive effort in public goods provision. However, the country's environmental record has been fair to poor, with delayed measures to address pollution. The government's response to popular demands is shaped by its autocratic nature, maintaining control over political processes. The term "state capitalism" aptly describes China's system, emphasizing state-led economic activities. While China has made strides in physical infrastructure, its environmental policies have lagged, underscoring a need for more effective public goods provision. [39]

China as a Hybrid Economic System

However, China's economic model stands as a fascinating case study in the realm of comparative economic systems. Contrasting it with traditional socialist regimes like those of the former Soviet Union or Cuba illuminates the distinctiveness of China's approach. While these regimes emphasized centralized planning and state ownership to varying degrees, China has embraced market-oriented reforms and encouraged private enterprise alongside state-owned enterprises. Similarly, juxtaposing China with capitalist economies such as the United States or European nations underscores the complexities of its hybrid system. Unlike pure capitalist systems that prioritize market forces and minimal government intervention, China maintains significant state control over key sectors and employs strategic planning to steer economic development. By examining these comparative dimensions, we gain deeper insights into the nuances and implications of China's unique economic trajectory.[40]

China's economic landscape reflects a complex dance between state control and market dynamics. Despite privatizing numerous productive assets, the government retains substantial control over income streams, illustrating a unique capacity to influence economic outcomes.

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[36] Kroeber, “What Everyone Needs to Know,”
[37] Pike, “China’s high-speed rail.”
[38] Lubin “China’s ‘renminbi trap.’”
[39] Lubin “China’s ‘renminbi trap.’”
[40] Pike, “China’s high-speed rail.”

With a considerable share of GDP under its sway, the Chinese government possesses the resources to mold economic trajectories through taxation and regulatory authority. This shift from a state capacity crisis to a situation where the government is formidable and resourceful signifies a distinctive departure from historical contexts.[41]

Central to China's economic structure is the government's substantial control over income streams and key sectors of the economy. Despite the introduction of market reforms and the rise of private enterprise, the state maintains significant ownership and regulatory authority, particularly in critical industries such as finance, telecommunications, and energy. This strategic control allows the government to shape economic outcomes, influence resource allocation, and steer development priorities in alignment with socialist objectives. [42]

In addition, China's economic structure challenges the notion that business owners are inherently socialist. The Chinese system has seen a surge in private enterprise, indicating a departure from traditional socialist ideals. However, the relationship between bureaucratic incentives and specific planning objectives, such as environmental goals, has been a long-term feature of the system. The tension between rewarding growth and addressing specific objectives reflects a complex interplay between socialist ideals and a more market-driven economic reality.[43]

A closer examination of specific industries, regions, or policies within China offers valuable insights into the workings of its hybrid economic model. For instance, exploring the transformation of China's manufacturing sector from state-dominated enterprises to globally competitive private firms reveals the interplay between socialist legacies and capitalist market dynamics. Similarly, analyzing regional disparities in economic development and the role of government intervention in poverty alleviation programs sheds light on China's inclusive growth agenda. Moreover, examining the impact of specific policies, such as the Belt and Road Initiative, provides concrete examples of how China integrates socialist objectives with capitalist mechanisms to achieve its economic goals. [44]

The private sector has played a pivotal role in driving China's remarkable economic growth over the past three decades. Despite the significant presence of state-owned enterprises (SOEs) in China's economy, it's the private sector that has been the primary engine of job creation, productivity improvement, and overall economic expansion. Currently, the private sector contributes approximately 85 percent of employment and manufacturing output, about two-thirds of GDP and fixed investment, and half of exports. Its importance has steadily increased, although recent years have seen a slowdown in the pace of its expansion. The evolution of the private sector can be understood in three phases: rapid expansion with insecure legal foundations in the late 1970s to mid-1990s, strengthening of private property rights and market access from the mid-1990s to 2008, and a period of stabilization and some setbacks post-2008, characterized by state-led policies that have somewhat constrained private sector

[41] Pike, “China’s high-speed rail.”
[42] Naughton, “Is China Socialist?”
[43] Hu and Khan, “Economic Issues 8.”
[44] Hu and Khan, “Economic Issues 8.”

growth.[45] Despite these challenges, the private sector remains a vital component of China's economy, and its continued growth will be crucial for sustaining China's economic trajectory in the future. However, for China to maintain robust economic growth, it must address inefficiencies in both the private and state sectors, including enhancing competition, strengthening financial discipline, and promoting reforms that support productivity and profitability across all segments of the economy.[46]

China's economic model plays a pivotal role in shaping its international relations and diplomatic engagements. By examining China's economic diplomacy and its implications for international relations, we gain insights into the evolving dynamics of global governance and economic cooperation. As China emerges as a global economic powerhouse, its interactions with capitalist countries and international organizations have become increasingly significant. Through initiatives like the Belt and Road Initiative and the Asian Infrastructure Investment Bank, China seeks to extend its economic influence and foster closer ties with countries across Asia, Africa, and Europe. Moreover, its participation in multilateral trade agreements and forums reflects its commitment to global economic integration while safeguarding its national interests. The Chinese government's commitment to internalizing the benefits of global economic integration is evident in its infrastructure projects, such as high-speed railways, creating a comprehensive grid and contributing to regional development.[47]

China has made impressive strides in technology, thanks to its special way of running things. Even though many Chinese people now work for themselves or private companies, the government still has a big say in crucial areas like banking, telecommunications, and education. They even control public media. This control gives the government a strong position in important sectors of the economy.[48]

The government's balance sheet shows they have a lot of assets, like land and state-owned businesses. Even though the government owes money, it's not as much as in some other countries. This means China's government is quite rich and has control over many assets in society. China's approach to making its economy work involves both letting businesses do their thing and the government stepping in when needed. The government encourages officials to focus on making the economy grow by offering them rewards. They also have plans that guide what they want to achieve over five years. This mix of letting businesses operate freely and government guidance has helped China become a major player in technology on the world stage.[49]

Moreover, China's approach to economic governance reflects a delicate balance between fostering business growth and ensuring state intervention when necessary. While embracing market dynamics and entrepreneurship, the government retains the authority to intervene through policies, regulations, and strategic planning initiatives. This hybrid model enables China to

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[45] Kornai, “Change of System,” 38.
[46] Kroeber, “What Everyone Needs to Know.”
[47] Kroeber, “What Everyone Needs to Know.”
[48] Kornai, “Change of System,” 38.
[49] Kroeber, “What Everyone Needs to Know.”

harness the dynamism of market forces while safeguarding social stability, promoting equitable development, and pursuing long-term economic objectives.[50]

Beyond its economic indicators, China's hybrid economic model has profound implications for society and culture. The coexistence of socialist principles and capitalist practices influences not only economic outcomes but also social welfare, cultural values, and individual behaviors. For instance, the emphasis on economic growth and material prosperity has led to rapid urbanization and changes in lifestyle patterns, impacting traditional social structures and community dynamics.[51] Moreover, the government's role in regulating media and information dissemination shapes public discourse and cultural expression, raising questions about freedom of speech and individual rights. By examining these broader societal and cultural dimensions, we gain a more holistic understanding of the complexities of China's economic development.[52]

Furthermore, China's economic trajectory highlights the interconnectedness between socialist aspirations and capitalist realities. While the government prioritizes socialist goals such as income redistribution, poverty alleviation, and social welfare, it also recognizes the importance of market mechanisms in driving efficiency, innovation, and productivity growth. This symbiotic relationship between socialist principles and capitalist practices underscores China's adaptive approach to economic development and its ability to navigate complex global economic dynamics.[53]

China's economic governance reflects a delicate balance between fostering business growth and ensuring state intervention when necessary. While embracing market dynamics and entrepreneurship, the government retains the authority to intervene through policies, regulations, and strategic planning initiatives. This hybrid model enables China to harness the dynamism of market forces while safeguarding social stability, promoting equitable development, and pursuing long-term economic objectives.[54] The coexistence of socialist principles and capitalist practices influences not only economic outcomes but also social welfare, cultural values, and individual behaviors. For instance, the emphasis on economic growth and material prosperity has led to rapid urbanization and changes in lifestyle patterns, impacting traditional social structures and community dynamics.[55] Moreover, the government's role in regulating media and information dissemination shapes public discourse and cultural expression, raising questions about freedom of speech and individual rights. By examining these broader societal and cultural dimensions, we gain a more holistic understanding of the complexities of China's economic development.[56]

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[50] Kroeber, “What Everyone Needs to Know.”
[51] Kroeber, “What Everyone Needs to Know.”
[52] Hu and Khan, “Economic Issues 8.”
[53] Kornai, “Change of System,” 38.
[54] Kornai, “Change of System,” 38.
[55] Hu and Khan, “Economic Issues 8.”
[56] Kroeber, “What Everyone Needs to Know.”

Conclusion

In conclusion, China's economic landscape presents a captivating amalgamation of socialist principles and capitalist practices, defying conventional categorizations of economic systems. Over the past four decades, China has embarked on a transformative journey, transitioning from a Maoist socialist regime to a hybrid model characterized by a unique blend of state-led initiatives and market-oriented reforms. While officially maintaining its socialist identity, China's economic evolution showcases a pragmatic integration of socialist ideals with capitalist mechanisms, resulting in a dynamic and resilient economic framework.[57]

In essence, China's hybrid economic model represents a paradigm shift in traditional economic thinking, challenging the dichotomy between socialism and capitalism. By embracing elements of both systems, China has forged a unique path toward prosperity, resilience, and global leadership. As the country continues to evolve and confront new challenges, its economic model serves as a testament to the power of innovation, adaptation, and pragmatism in shaping the future of global economics.[58] This underscores the intricate interplay between socialist ideals and capitalist economic structures, showcasing China's unique economic path and its ability to navigate the complexities of a rapidly changing global economic landscape.[59]

The country's emphasis on public goods provision, epitomized by extensive investments in infrastructure development, underscores its commitment to enhancing collective well-being and promoting inclusive growth. China's extensive high-speed rail and highway networks, coupled with ambitious urban development projects, reflect a concerted effort to improve connectivity, enhance mobility, and stimulate regional economic development.[60] However, challenges persist, particularly in addressing environmental degradation and mitigating the adverse effects of rapid industrialization and urbanization.[61]

Looking ahead, China's hybrid economic model faces a myriad of opportunities and challenges. While the model has propelled China to unprecedented economic growth and global prominence, questions remain about its long-term sustainability and adaptability. Challenges such as environmental degradation, income inequality, demographic shifts, and technological disruptions pose significant hurdles to China's continued development. Moreover, geopolitical tensions and trade conflicts with capitalist countries introduce additional uncertainties. Addressing these challenges will require bold reforms, innovative policies, and proactive measures to strike a delicate balance between socialist ideals and capitalist realities. By exploring these future prospects and challenges, we gain insights into the resilience and dynamism of China's economic model in an ever-changing global landscape.[62, 63]

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[57] Pike, “China’s high-speed rail.”
[58] Pike, “China’s high-speed rail.”
[59] Hu and Khan, “Economic Issues 8.”
[60] Kornai, “Change of System,” 38.
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Applications of Crispr Technology in Cancer Research and Treatment by Tvissha Pilani

Abstract

Through clustered, regularly interspaced short palindromic repeat (CRISPR) systems, bacteria and archaea have developed adaptive immunity against invading genetic material. The discovery of this fascinating facet of bacterial immune systems have signalled a significant and drastic shift in the study of oncology and medicine as a whole. The molecular technique based on CRISPR technology and CRISPR-associated protein 9 (Cas9) has been used for genome editing. Now, the CRISPR-Cas9 method can be used to introduce exact genetic alterations or disruptions in both in-vitro ("In vitro" refers to experiments conducted outside of a living organism, typically in a lab environment like test tubes or petri dishes.) and in-vivo ("In vivo" refers to experiments conducted within a living organism) settings. Research in biology and medicine has benefited from the precision and adaptability of the CRISPR-Cas9 system, which amongst the various applications, has given cancer research fresh hope. Multiple mutations, translocations, chromosomal gains, and other complicated changes all occur in the development of cancer.

An important objective of cancer treatment is the capacity to recognise and correct such alterations. Having a straightforward and adaptable genetic approach in the toolbox that can quickly and readily identify functional cancer driver genes, is required in the setting of a complicated cancer genomic landscape. The CRISPR-Cas9 system exhibits significant potential for simulating, mending, and reversing genomic changes in several cancer types. This article examines the theory behind CRISPR-Cas9, as well as its applications in oncology.

Keywords

CRISPR-Cas9, Genetics, Cancer Research, Oncology, Gene editing

Introduction

Over the centuries, advances in medical technology have led to the eradication of many diseases that were once deadly. Many of the treatments, diagnostics and medical procedures have been deployed as a result of dramatic developments in genetic engineering. In the past decade, many scientists have used genetic engineering to edit a specific site in the genome of various organisms such as mice, rabbits, cattle, and even humans to either add, or remove singular base pairs of DNA or even whole genes. Today, CRISPR is the fastest and one of the most accurate methods of genetic engineering. CRISPR was derived from the immune system response in prokaryotes.

Cancer is the second leading cause of death around the world with around 10 million deaths in 2022. It has become a worldwide public health problem. Current therapies are only capable of fighting certain cancers in the early stages. Medical professionals are constantly on the hunt for new technology not only to improve cancer treatment but also its early detection. Employing CRISPR-cas9 technology to cancer research, treatment and detection has proved to be extremely beneficial. CRISPR has been applied to several in-vivo and in-vitro cancer models,

and holds promise for improving cancer immunotherapy approaches. For example, CRISPR can be used to edit T cells or other immune cells to enhance their ability to recognize and attack cancer cells. By targeting specific genes, researchers can modify immune cells to be more effective in anticancer activity. CRISPR also allows the creation of more accurate and realistic cancer models, such as GEMMs, which can then be used, amongst other studies, to track tumor responses to therapy.

By introducing specific genetic alterations in mice that are found in human cancers,, researchers can better understand the progression of the disease and test potential therapies in a more realistic context. CRISPR plays a pivotal role by allowing scientists to activate and deactivate specific genes. This ability can be applied to oncogene (genes that promote cancer) and tumor suppressor genes that inhibit cancer cells genetic studies. Using CRISPR, researchers can study the function of these oncogenes and tumour suppressor genes () by manipulating their activity in cancer cells. By activating and deactivating these genes, scientists can better understand their role in cancer progression. Moreover, CRISPR also enables conditional genetic modification in animal cancer models. This means that specific genetic alterations can be activated and deactivated at specific times, or in specific tissues. By being able to control the timing and the locations of these modifications, researchers can better mimic the natural progression of cancer in humans and investigate the role of specific genes in different stages of tumorigenesis.

CRISPR can also be used to aid in the delivery of therapeutic agents such as drugs or genes to cancer cells. CRISPR based systems like Crispr-Cas9, can be engineered to carry specific loads of therapeutic agents and selectively target cancer cells. This approach potentially offers a means of delivering targeted therapies directly to tumours, minimising the negative side effects inflicted on healthy tissues.

Timeline of CRISPR

CRISPR were first discovered in DNA sequences from Escherichia coli and described in 1987 by Ishino from Osaka University. At that time, it took many months to sequence these challenging-to-study DNA snippets, but neither their origin nor their importance in the bacterial cell were known by their discoverers. Although the biological function of the CRISPR system was not fully understood in the early work in this field, scientists had already proposed a method to use CRISPR in medical research, mainly for genotyping different bacterial strains, initially on Mycobacterium tuberculosis and later, on Streptococcus pyogenes. As it turned out, the CRISPR loci displayed a significant degree of variability in several strains of the same type of pathogenic bacteria, allowing the identification of bacterial strains in clinical situations.

Francisco Mojica of the University of Alicante, who discovered comparable structures in the archaeal genome of Haloferax mediterranei in 1995, made significant improvements to our understanding of the biological function of CRISPR. Mojica was one of the first researchers to propose that these unusual loci contain foreign DNA fragments and are, in fact, a component of the immune system of bacteria and archaea after observing similarities between the elements he

described in archaea and previously discovered DNA repeats in bacterial genomes. In the same year as Mojica, two more laboratories independently came to similar conclusions, indicating the start of a period of active investigation into this extraordinary natural phenomenon.
According to the prokaryotic immune system theory, viral DNA fragments are separated by brief palindromic repeats . At first, it was thought that RNA interference would be the mechanism by which such a system worked. The use of such a system in the lab could therefore represent a potential tool for genomic editing.

However, it was experimentally demonstrated for the first time in the publication by Marraffini and Sontheimer, that the actual target of the immune system of prokaryotes was foreign DNA, and not mRNA. Furthermore, additional studies showed that some of the described CRISPR systems do interact directly with RNA molecules and can, thus, be used to selectively deactivate particular transcripts inside the cell.

The studies of two French food scientists, Rodolphe Barrangou and Philippe Horvath, who worked with yoghurt cultures of the bacteria Streptococcus thermophilus for the Danish company Danisco, yielded the first experimental data about the mechanism of action of the CRISPR system in 2007. Researchers were able to track the long history of the bacterial acquisition of spacers at the CRISPR locus in response to viral attacks by bacteriophages thanks to the business' collection of bacterial strains obtained since the 1980s. In this research, new spacers were added, and S. thermophilus developed resistance to the corresponding new types of bacteriophages. This discovery resulted in the authors' acquisition of one of the initial patents in this field and the beginning of the "vaccination" of bacterial cultures by Danisco using CRISPR-based technology in 2005.

Application of CRISPR in the Delivery of Therapeutic Agents :

CRISPR can be used to deliver drugs, genes, and other therapeutic agents to cancer cells. By modifying the guide RNA or cas9 protein, researchers can attach therapeutic cargo to the CRISPR complex. Through mediated delivery the CRISPR system guides the cargo to the target site within the genome, allowing for precise delivery of the therapeutic agent to the cancer cells.

CRSIPR based therapeutic agents can be delivered to cancer cells using non-viral delivery methods, by encapsulation CRISPR complexes within liposomes, nanoparticles or other carriers. This delivery system protects the CRISPR cargo and facilitates its uptake into cancer cells. The delivery vehicle can also be modified to enhance cell targeting and improve the efficiency of the delivery. Viral delivery can also be used as a delivery method. Viral vectors such as lentiviruses or adeno-associated viruses, can be engineered to deliver CRISPR-based therapeutic agents to cancer cells. The therapeutic cargo is packaged within the viral vector, which can efficiently infect cancer cells and deliver the CRISPR payload. Viral vectors have the advantage of high transduction efficiency and long-term gene expression in target cells. Localised delivery methods can be employed to directly deliver CRISPR based therapeutic agents. In the case of solid tumours the therapeutic agents can be directly injected or administered by implantable scaffolds or hydrogels.

Crispr in cancer modelling

Genetic mutations and epigenetic alterations play significant roles in tumorigenesis. Cancer is a multi-hit disease that is a result of mutations in genes involved in the control of cellular function, growth and division. Epigenetic modulation and genome editing are important for cancer modelling and therapeutic efficacy. The whole-genome sequencing data of human cancer cells exposed the complexity of the cancer genome, including numerous point mutations and large genome rearrangements. Cell and animal models can be established using these data in order to understand the molecular mechanisms underlying tumorigenic responses. New candidate genes to be considered as target genes for cancer therapy can also be validated through the use of these models.

CRISPR has proven itself to be a powerful tool in identifying drug resistance genes in cancer. Drug resistance is a significant challenge in cancer treatment, where cancer cells develop the ability to evade the effects of anticancer drugs, leading to treatment failure. Various methods are used to determine the role of drug resistance in cancer.

1. Loss-of-Function Screens: In these screens, CRISPR is used to specifically disrupt or knock out individual genes in cancer cells. By systematically targeting thousands of genes, researchers can identify genes whose loss leads to increased sensitivity to a specific drug. These genes may act as drivers of drug resistance when present.

2. Gain-of-Function Screens: In these screens, CRISPR is used to introduce specific genetic alterations, such as activating mutations or gene overexpression, into cancer cells. By introducing these alterations across the genome, researchers can identify genes that, when overexpressed or mutated, confer resistance to certain drugs.

3. Genomic Editing of Known Drug Resistance Genes: CRISPR can be used to specifically edit genes known to be associated with drug resistance in cancer. By introducing specific mutations or modifications in these genes using CRISPR, researchers can confirm their role in mediating drug resistance and further investigate their mechanisms of action.

4. Modelling Drug Resistance in Cell Lines: CRISPR technology allows the creation of cell lines with specific drug resistance gene alterations. By introducing resistance-associated genetic alterations into cancer cell lines using CRISPR, researchers can study the impact of these alterations on drug response and identify the molecular mechanisms that contribute to drug resistance

5. Functional Validation of Candidate Genes: Once potential drug resistance genes are identified using CRISPR screens or other approaches, functional validation can be performed with CRISPR technology. By selectively editing the expression or activity of

these genes, researchers can confirm their role in drug resistance and explore potential strategies to overcome resistance.

CRISPR in brain cancer

Brain cancer is the most lethal among all cancers, regardless of gender and age. The therapies used against brain cancers such as gliomas have been more or less the same for the last five decades. There are also technical difficulties in the clinical management of brain cancer. For these reasons, researchers are trying to find solutions at the genetic level. In this context, CRISPR-Cas9 can be an efficient, convenient and less time-consuming technique.

Colorectal cancer

Colorectal cancer (CRC) arises from the colon or rectum. Tumor sequencing studies have revealed a significant number of candidate genes that are mutated in CRCs. These genes contribute to carcinogenesis, tumor phenotype and tumor progression. Functional assessment of putative cancer-associated genes usually requires in vivo experiments; in this context, GEMMs are being used. In studies using GEMMs, application of the CRISPR-Cas9-based editing system in orthotopic organoid transplantation of mice without cancer-predisposing mutations corrected the APC and TRP53 tumor suppressor genes in colon epithelial cells. For engraftment at ectopic sites in mice, mutations in APC, TP53, KRAS, SMAD4 and PIK3CA were needed. This approach can be applied in different methods and/or different arrangements, depending on the goal of the experiment, and can be a crucial tool for determining the types of mutations that are most potent in transforming cells, thereby conferring a growth advantage in a multiclonal tumor.

Cervical cancer

Cervical cancer is another common cancer having worldwide incidence in women. Human papillomavirus (HPV) is thought to be a major causative agent of cervical cancer. During HPV infection, the viral oncoprotein E6 promotes degradation of the host tumor suppressor protein p53, promoting malignant transformation of normal cervical cells. The CRISPR-Cas9 system was used to disrupt the HPV16 E6 gene. HPV16 E6 deoxyribonucleic acid was cleaved at particular sites, leading to apoptosis of HPV16-positive SiHa and CaSki cells. The HPV16 E6 ribonucleic acid-guided CRISPR-Cas system can be an effective therapeutic agent in cases of cervical malignancy related to HPV infection.

Conclusion:

Cancer presents a long-standing problem in the history of human health and so far has no holistic solution. Researchers from various parts of the world are searching relentlessly for an appropriate and efficient approach based on genetic technology that can provide a sustainable solution to this disease. The CRISPR-Cas9 system is cuttingedge gene-editing technology with wide potential that stands alone among other genetic techniques of gene editing in cancer-related diseases.

Conclusion

In conclusion, the future of CRISPR technology is poised to revolutionize multiple domains, particularly in medicine, agriculture, and biotechnology. Its potential to precisely edit genes offers groundbreaking possibilities for treating genetic disorders, developing targeted cancer therapies, and enhancing crop resilience. However, realizing this potential will require overcoming technical challenges, addressing ethical concerns, and establishing robust regulatory frameworks. As research and development continue to advance, CRISPR technology is set to become an invaluable tool in improving human health, ensuring food security, and driving innovation across various industries, heralding a new era of genetic and biotechnological progress.

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A Meta-Analysis Comparing the Prevalence of Chronic Fatigue Syndrome in Low and High Socioeconomic Status Populations by Liv Rhee

Abstract

Myalgic encephalomyelitis (ME), also known as chronic fatigue syndrome (CFS), is a debilitating condition defined by extreme, prolonged fatigue. The causes of ME/CFS are currently unknown; however, some evidence suggests that chronic fatigue syndrome arises from a combination of factors including infections, immune system challenges, stress, changes in energy production, and genetics. This begs the question: Is there a direct correlation between socioeconomic status and the prevalence of chronic fatigue syndrome? Through a meta-analysis, this paper will explore the hypothesis: Given that lifestyle and environmental factors may contribute to chronic fatigue syndrome, it is possible that there may be a difference in prevalence in CFS based on socioeconomic status. This paper considers studies done in the United States and the United Kingdom over the last 25 years and finds a higher prevalence of CFS amongst individuals with higher socioeconomic status.

Introduction

Myalgic encephalomyelitis, also known as chronic fatigue syndrome (CFS), is a disabling illness defined by various, long-term symptoms. The main symptom of chronic fatigue syndrome is extreme fatigue and the inability to complete activities that an individual could do before getting the illness. To be diagnosed with CFS, this fatigue must last for six months or longer. Furthermore, the fatigue is not relieved by sleep or rest, not a result of a difficult activity, and was not a problem to the person prior (Sapra). A symptom closely related to fatigue is post-exertional malaise (PEM), also known as “crashes,” in which the individual’s symptoms and fatigue worsen for a certain period of time. Recovery from these “crashes” can take weeks (CDC). Individuals with CFS may also experience sleep problems and trouble with thinking and memory, also known as “brain fog.” Some less common symptoms include muscle aches, headaches, tender lymph nodes, a sore throat, digestive issues, chills, and irregular heartbeat. Individuals are diagnosed based on an evaluation of a person’s symptoms and medical history (CDC). Because there is no specific test for CFS, diagnosis can be challenging, making it difficult to acquire accurate data for the prevalence of CFS. It is estimated that 836,000 to 3.3 million Americans have CFS and 250,000 people in the United Kingdom have CFS (CDC; The ME Association).

The causes of CFS are currently unknown. Research shows that CFS may be caused by a combination of factors, including infections, immune system challenges, stress, changes in energy production, and genetics. Often people are sick with an infection before getting CFS. Research suggests that infections and also stress can weaken the immune system, causing an individual to be more susceptible to CFS. In terms of immune system challenges, it’s possible the immune system produces an excessive amount of cytokines, which lead to a change in the body’s response to stress and infections. Research also shows that natural killer cells are

low-functioning in individuals with CFS. Natural killer cells are a type of lymphocyte that target and eliminate infected cells and tumor cells. Thus, when individuals have low-functioning natural killer cells, their immune system is less able to fight off infections and viruses. Additionally, there may be differences in the markers of T cell activation in individuals with CFS. T cells are another important component to immune system responses. When T-cells identify antigens, they proliferate into various subtypes that eliminate abnormal cells. Specifically, T cells are able to release cytokines—proteins that help regulate immune response—to fight off infection. Without normal functioning T cells, individuals can be more susceptible to illness. CFS also appears to run in families (CDC).

Evidence suggests that certain populations are more at risk for chronic fatigue syndrome. CFS is most common in individuals between 40-60 years of age. Additionally, the ratio of women to men with CFS can be up to 4 to 1. Research shows that White non-Hispanics are more likely to have CFS; however, it is currently unclear if this is because White non-Hispanic individuals are more likely to receive diagnoses and treatment. Therefore, although results show that CFS is less common in African Americans and Hispanic persons, this may not be the reality, especially considering social adversity can increase an individual's likelihood of getting CFS (“Chronic Fatigue Syndrome.”).

Multiple studies have recorded socioeconomic status (SES) levels for individuals with CFS, but the correlation between the two is still unclear. Given that social adversity and excessive physical activity are factors in developing CFS, it’s possible that there may be a strong correlation between socioeconomic status and CFS. Therefore, the aim of this paper is to discover if there is a relationship between socioeconomic status and the prevalence of chronic fatigue syndrome. The findings of this paper can give more insight into why CFS manifests in certain individuals and if there are certain populations that should be the targets of treatment.

Methods

To determine if there is a correlation between chronic fatigue syndrome and socioeconomic status, a meta-analysis was employed. A meta-analysis is a quantitative statistical analysis of a combination of several past experiments or studies that addressed a similar issue. A meta-analysis was chosen as the method of this study because it synthesizes the findings of multiple studies and therefore, gives a more accurate result.

Nine papers were found using Google Scholar and PubMed. Keywords included: chronic fatigue syndrome, Myalgic Encephalomyelitis, socioeconomic status, education, income, occupation, demographics, United States, United Kingdom, prevalence, correlation, adult. The papers were chosen if they recorded the prevalence of chronic fatigue syndrome and had some measure of socioeconomic status for each individual—either education (5 studies), income level per year (3), or employment/occupation (1). Furthermore, all studies were either conducted on participants from the United States (6 studies) or the United Kingdom (3). Populations were pulled from the United States and United Kingdom because of their similar economic and social structures. Due to their similar structures, the assumption can be made that population samples

from both countries will be similar. Most of the studies used were population or community based studies, where participants were taken from a city or region. A population or community based study is a study that takes a sample that shares a trait, such as living in the same city, and looks for distinct trends within the sample (National Cancer Institute). This was the ideal sample collection method because it gave a more accurate representation of the prevalence of CFS between different demographic groups. An issue with the studies that took participants from medical databases was that individuals with lower socioeconomic statuses may not have access to healthcare, and therefore, may not have been diagnosed with CFS. This skews the data to prefer individuals with higher socioeconomic statuses.

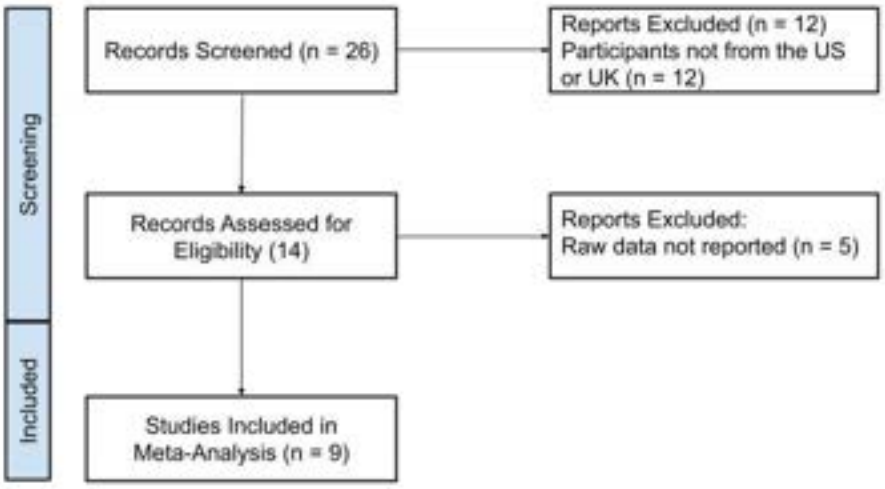


Fig 1: Screening and identification of studies with raw numbers, and exclusion and inclusion criteria.

The first step for extracting data from the studies was to define low and high socioeconomic status. Multiple sources were consulted to determine the criteria for both low and high socioeconomic status (ASPE; The Ascent; "Social Class in the United States"). The criteria for low socioeconomic status is: only completing education to high school, being unemployed or employed as an unskilled worker, and/or earning less than or equal to 40,000 dollars per year. Specifically, an unskilled worker is a worker with a job that only requires a high school diploma. On the other hand, the criteria for high socioeconomic status is: being educated beyond high school (including partial college), being self-employed or employed as a semi-skilled/skilled worker, and earning more than 40,000 dollars per year.

After defining low and high socioeconomic status, raw data was extracted from each paper. This included the total number of people with chronic fatigue syndrome and the number of people who qualified for low and high socioeconomic status out of that group, given the criteria above.

Papers that did not include the raw numbers were excluded. Additionally, only one measure of socioeconomic status was used to categorize participants per paper and the order of reliability from least to greatest was employment, education, and income. For instance, if a paper measured both an individual's employment status and income, income would be used as the measure of socioeconomic status. The reasoning behind this ranking was that employment status could be determined by a number of factors and it is unclear if a person is retired or actively searching for a job. In terms of education, it is typically more reliable than employment because a higher education is more correlated with a higher socioeconomic status. However, the best measure was income because that directly correlates with socioeconomic status, and is typically used as the measure of socioeconomic status (Daly et al).

Table 1: Information of each study used in the meta-analysis, including author, location, population size, method of data collection, measure of SES, and the citation.

Citation	Location	Population size	Method of data collection	What was recorded to measure SES
Bhui, K. S., et al. BMC Medicine, vol. 9, no. 1, 2011.	UK	97	Survey data from Health Survey for England (1998 and 1999).	Occupation
Kingdon, C. C., et al. *PharmacoEconomics Open*, vol. 2, no. 4, 2018, pp. 381–392.	UK	52	Data from UK ME/CFS Biobank.	Education
Stevelink, S. A. M., et al. *Occupational Medicine*, vol. 69, no. 6, 2019, pp. 453–458.	UK	504	Cross-sectional data from patients attending a UK specialist CFS treatment service.	Education
Bierl, C., et al. *Population Health Metrics*, vol. 2, no. 1, 2004.	US	49	Pilot random-digit-dialing survey in different geographic regions.	Income
Jason, L. A., et al. *Archives of Internal*	US	32	Select 1 adult from each household in 8 Chicago	Education

Medicine, vol. 159, no. 18, 1999, pp. 2129–2137.			neighborhoods; the person with the most recent birthday was interviewed.	
Reyes, M., et al. *Archives of Internal Medicine*, vol. 163, no. 13, 2003, p. 1530.	US	43	Random digit–dialing survey to residents in Wichita, Kansas.	Income
Nisenbaum, R., et al. *Health Quality Life Outcomes*, vol. 1, 2003, p. 49.	US	65	Random-digit-dialing survey of Wichita, Kansas residents.	Income
Wiedbusch, E., et al. *Journal of Preventive Medicine & Healthcare*, vol. 3, no. 1, 2021, p. 1018.	US	209	Data from the SolveCFS BioBank	Education
Bhatia, S., et al. *American Journal of Social Sciences and Humanities*, vol. 5, no. 1, 2020, pp. 104–115.	US	234	Data from the SolveCFS BioBank.	Education

The risk ratio is a value that compares the prevalence or risks for two groups (Dettori). A risk ratio of 1 would imply that both groups are at the same level of risk. To find the risk ratio of chronic fatigue syndrome between individuals with low socioeconomic status and high socioeconomic status within the same study, the raw number of people with CFS that qualified for high SES was divided by the number that qualified for low. Calculations for standard error for low and high SES used a method called bootstrapping. Bootstrapping is a statistical procedure where a single dataset is recreated over multiple simulated samples to create an estimation of error (Joseph). To find standard error for low SES, the number of people with CFS who met the criteria for low SES and the total number of people with CFS was entered into StatKey. Statkey is an open source online statistical tool for bootstrapping ("Bootstrap Confidence Interval for a Proportion."). Similarly, to find standard error for high SES, the number of people with CFS who met the criteria for high SES and the total number of people with CFS was plugged in to Statkey again.

To find the common standard error, a propagation of error calculation was executed, as shown below:

$$\Delta Z = Z \cdot \sqrt{\left(\frac{\Delta X}{X}\right)^2 + \left(\frac{\Delta Y}{Y}\right)^2}$$

Eq 1

In Eq 1, Z symbolizes the risk ratio, ΔX is the standard error for low SES, X is the raw number of people with low SES, ΔY is the standard error for high SES, and Y is the raw number of people with high SES. This calculation gives us ΔZ, which is common standard error.

Low and high confidence intervals were determined through the following formulae:

L CI = risk ratio - (2*ΔZ)
H CI = risk ratio + (2*ΔZ)
Eq 2

The weight of each study---the effect that a particular study has on the results relative to other studies in the analysis---was calculated by taking the total number of participants used from that study (total number of people with CFS) and dividing it by the total number of people with CFS, used from all the studies. This number was then multiplied by 100, thus finding the percentage of the total number of people used in the meta-analysis that were from the specific study.

The risk ratio, low confidence interval, high confidence interval, and weight were used to generate a forest plot through the High Yield Medicine forest plot generator ("Forest Plot Generator.").

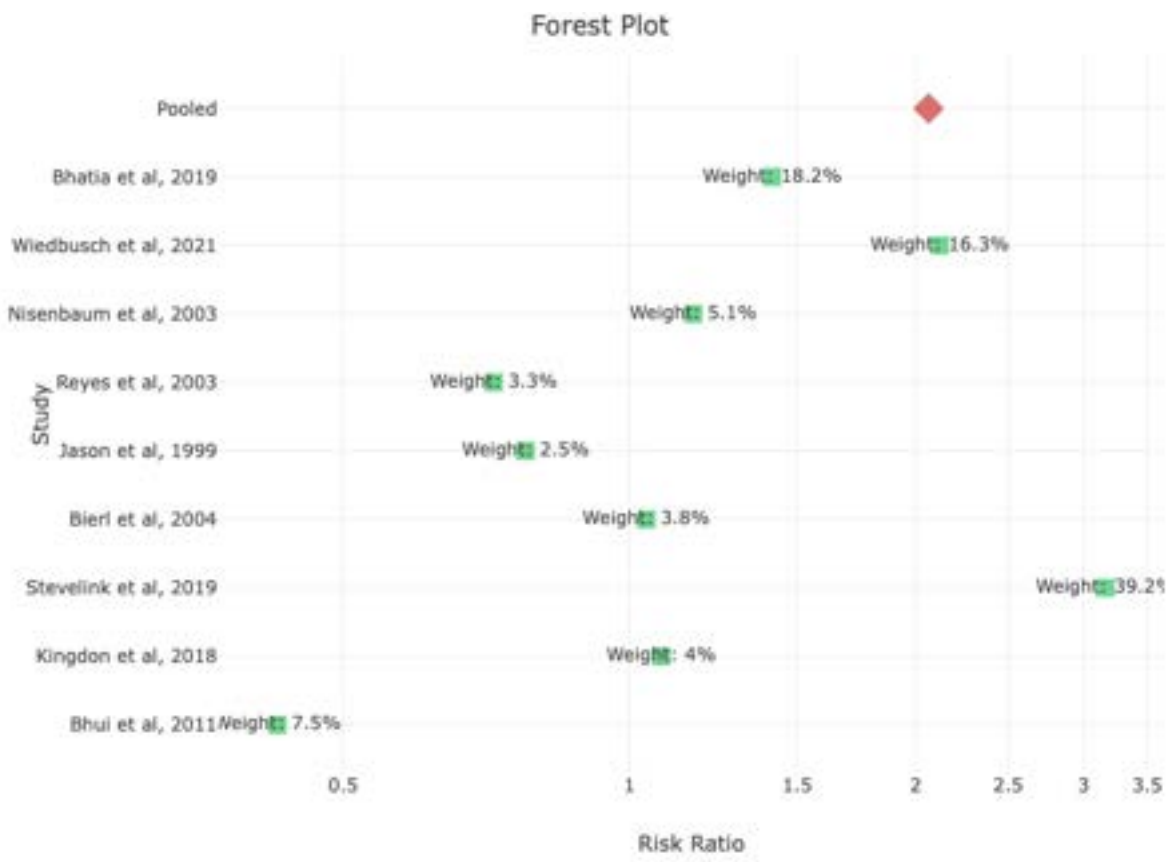
Results

The data collected was a compilation of raw data from 9 different studies with participants that have chronic fatigue syndrome and some measure of socioeconomic status (income, education, occupation). Most participants were above 18 and from the United States or the United Kingdom.

Table 2: Table of studies, with calculated risk ratio, confidence interval generated by bootstrapping, and weights generated for each study based on chronic fatigue syndrome patient population size.

Study	Risk Ratio	Lower CI	Upper CI	Weight
Bhui et al, 2011	0.43	0.42	0.43	7.5
Kingdon et al, 2018	1.08	1.07	1.09	4.0
Stevelink et al, 2019	3.17	3.16	3.17	39.2.
Bierl et al, 2004	1.04	1.03	1.05	3.8
Jason et al, 1999	0.78	0.77	0.79	2.5
Reyes et al, 2003	0.72	0.71	0.73	3.3
Nisenbaum et al, 2003	1.17	1.16	1.17	5.1
Wiedbusch et al, 2021	2.12	2.12	2.12	16.3
Bhatia et al, 2019	1.41	1.41	1.41	18.2

Above is the table of each study, with the author and date of the study in the left column. For each study, the risk ratio, lower confidence interval (Lower CI), upper confidence interval (Upper CI), and weight were calculated as described in the methods section. The confidence intervals for each study were very close to the risk ratio. There was a large range in the weight of each study as well.



Pooled Risk Ratio: 2.06

95% CI: [2.06, 2.07]

Heterogeneity: 2.06

Figure 2: Forest plot comparing the risk ratios of studies. Pool statistic at 2.06±0.00.

Each green point on the forest plot represents one of the studies, which are shown on the y-axis. The risk ratio serves as the x-axis. The green boxes range from the lower confidence interval to upper confidence interval for each study; however, given that the studies had small confidence intervals, the boxes do not span far. There are three studies with a risk ratio to the left of 1 and six studies with a risk ratio to the right of 1.The red diamond represents the pooled statistic, which was at a risk ratio of 2.06. Although seven of the studies are to the left of the pooled statistic, the pooled statistic heavily leans to the right because the two studies on the right (Wiedbusch et al and Stevelink et al) are weighted heavily.

Discussion

As the summary statistic was 2.06, the results propose that the odds of an individual with chronic fatigue syndrome being of high socioeconomic status is 2.06 times greater than their odds of being of low SES.

An explanation for this result is there may be a bias towards diagnosing chronic fatigue syndrome amongst higher socioeconomic status populations. Individuals in lower socioeconomic situations tend to be underdiagnosed, especially with an illness like chronic fatigue syndrome, which cannot be easily diagnosed and can be confused with other illnesses. Not only do lower income individuals have less medical resources, but they are also under different societal expectations where it might be less acceptable or believable to have CFS. CFS may be confused with depression or just general fatigue from working.

A counterpoint to this is that the studies chosen for this meta-analysis were mostly population based. In other words, the majority of the studies randomly selected participants from a certain region, which could have given a more accurate representation of the total population. The studies with this sampling method could have also been more reliable because they diagnosed all participants with CFS themselves. However, these methods still hold bias. Participants could have had different ideas of the severity of their own symptoms, and thus, two people with the same symptoms could have been diagnosed differently.

Furthermore, Wiedbusch and Bhatia's study sampled from a medical database, where they took participants who were already diagnosed with CFS. As Wiedbusch took 209 and Bhatia took 234 individuals with CFS from the SolveCFS BioBank, it's possible that the majority of these individuals were of high SES because they had resources—which people of low SES may not have had—to become diagnosed. This would give an unreliable representation of the total population, and be inaccurate to the real ratio of low and high SES individuals with CFS. Therefore socioeconomic status would not affect who is entered into the data. Therefore, it is still highly likely that the data could have been skewed to favor individuals with high socioeconomic status through sampling methods in studies. Therefore, inconsistencies in how SES was reported for these studies and differences in how study results were collected makes it difficult to rule out diagnosis bias as a confounding variable in these results.

Another potential limitation was the criteria for low SES and high SES. It's possible that the definition of low SES may have been too low, as a yearly income of above 40,000 dollars was considered high SES. 40,000 dollars is a relatively very low yearly income, only 10,000 dollars greater than what is considered poverty according to the U.S. Department of Health and Human Services in 2024 ("What Income Is Considered Poverty Level in 2024?"). If the definition of low SES was too low, then some participants that made the criteria for high SES might be mislabeled, which would skew the results towards high SES. Furthermore, because of the difference in the countries economies, it may not have been appropriate to apply the same criteria for SES for both countries. This could result in miscategorizing participants into low or high socioeconomic status.

Additionally, the method of determining SES through education and occupation may not have been completely accurate and reliable. Socioeconomic cannot necessarily be inferred through education and occupation. For instance, a person with a college graduate degree may not necessarily be of high socioeconomic status, especially given financial aid. Similarly, a person who has a job that requires manual labor may not necessarily indicate low SES. Given the limitations for the criteria, participants may have been further miscategorized and biased the results towards high SES.

Another limitation is the other demographic factors of each participant that could have affected the results. For instance, some of the studies included participants under 18. Results from previous research suggest that CFS is more common among adults, usually 40-60 years old ("Chronic Fatigue Syndrome."). Furthermore, it is possible that some of the participants are not from the United States or United Kingdom, and have only lived in the US or UK for a short period of time. Additionally, all genders were included in the meta-analysis, which could affect the results because CFS is more common among women than men ("Chronic Fatigue Syndrome."). Lastly, all races and ethnicities were included in the report. These four external factors could have contributed to a variance in the results. To improve the strength and accuracy of the results in the future, it would be beneficial to analyze these populations separately.

In conclusion, this research paper determined that there is a strong correlation between the prevalence of chronic fatigue syndrome and individuals with high socioeconomic status. Specifically, the odds that an individual with chronic fatigue syndrome would be high socioeconomic status is 106% higher than if they were low socioeconomic status. These findings can inform researchers to conduct new studies that determine why the prevalence of CFS is higher in populations of high SES. Exploring and discovering the reason for this difference could allow researchers and doctors to reduce or prevent the development of chronic fatigue syndrome in the future.

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Etiological Theories of Comorbid Substance Use Disorder and Schizophrenia
By Oruebubechukwu Asogwa

Abstract

Substance use disorder and schizophrenia are both chronic mental illnesses with serious complications. There is a clinical overlap between symptoms of schizophrenia and symptoms of substance withdrawal, intoxication, and chronic use. Numerous theories have been proposed to explain the connection between schizophrenia and substance abuse disorders, but it remains unclear. These theories consist of the neural diathesis-stress model, accumulative risk factor model, common factor model, affect regulation model, and schizophrenia causes drug use (self-medication model). Despite these various theories, recent work has shifted towards exploring the role of genetics and neural circuit dysfunction in explaining the comorbidity. This literature review aims to evaluate the etiological theories regarding comorbid substance use disorder and schizophrenia.

Introduction

Many epidemiological studies show an elevated risk of substance use among patients with schizophrenia. The lifetime prevalence rate of substance use disorder among patients with schizophrenia is approximately 50% (Fowler et al.,1998; Kessler et al., 1997; Regier et al., 1990), and the comorbidity affects both first-episode schizophrenia and those in the prodromal stage (Rosen et al., 2006). The Epidemiological Catchment Area study done in the United States shows that the most used substance by people with schizophrenia is nicotine, with a prevalence rate of 90% (Regier et al., 1990). The prevalence rates of other abused substances among patients with schizophrenia are cannabis (37%), alcohol (34%), cocaine (31%), amphetamine (12%), opioids (12%), hallucinogens (4%), and sedatives (3%) (Maremmani et al., 2017).

Schizophrenia, a debilitating illness, is ranked by the World Health Organization as one of the leading illnesses that contribute to the global burden of disease (Murray & Lopez, 1996). Its lifetime prevalence rate is about 1% worldwide (Bhugra, 2005). Substance use disorder can complicate making an early diagnosis of schizophrenia and result in delayed treatment (Green et al., 2004). Other effects of substance use disorder on the course of schizophrenia include increased relapse of psychotic symptoms leading to increased hospitalizations with the increased cost of care, noncompliance with treatment, criminal offenses, suicidal behaviors, homelessness, and increased risk of infections like hepatitis C infection and human immunodeficiency virus (HIV) infection (Dixon, 1999; Hunt et al., 2002; Lacro et al., 2002; Gut-Fayand et al., 2001; Cantor-Graae et al., 2001; Rosenberg et al., 2001; Gerding et al., 1999; Hoff & Rosenheck,1999; Lähteenvuo et al., 2021). Co-occurrence of schizophrenia and substance use disorder is associated with increased mortality (Lähteenvuo et al., 2021; Heiberg et al., 2018; Plana‐Ripoll et al., 2020; Reininghaus et al., 2015), with substances like cocaine, heroin, and alcohol reported to be more lethal than cannabis (Heiberg et al., 2018; Reininghaus et al., 2015; Schmidt et al., 2011; Hjorthøj et al., 2015; Koola et al., 2012; Björkenstam et al., 2012; Crump et al., 2013; Lumme et al., 2016).

Studies show that risk factors such as young age, being male, living in an urban area, incarceration, and homelessness among patients with schizophrenia increase the risk of comorbid substance use disorder (Lybrand & Stanley, 2009; Mueser et al., 2001; Tsai & Rosenheck, 2013). Many hypotheses try to explain the co-occurrence between schizophrenia and substance use disorder. These hypotheses include the self-medication hypothesis, which explains that patients with schizophrenia use substances to treat the side effects of antipsychotics or to treat symptoms of psychosis (Khantzian, 1997). The shared etiology hypothesis (common factor model) explains that schizophrenia and substance use disorder share the same genetic vulnerabilities and socioeconomic factors (Guloksuz et al., 2019; Khokhar et al., 2018; Chambers et al., 2001; Roth et al., 2005; Green et al., 1999). The neural diathesis-stress model explains that interaction between genetic vulnerabilities and environmental risk factors such as substance use leads to the onset of schizophrenia (Fowles, 1992). The cumulative risk factor hypothesis proposes that patients with schizophrenia with low social, educational, vocational, and cognitive abilities are at increased risk of substance abuse (Mueser et al., 1998). Another proposed etiological hypothesis to explain the comorbidity between schizophrenia and substance use is Blanchard's affect regulation model (Blanchard et al., 2000). While these models are supported by various prior research, there is no consensus on the theory that best explains the pathophysiology of comorbid substance use disorder and schizophrenia.

The purpose of this literature review is to evaluate the notable theories that explain the comorbid substance use disorder in schizophrenia, comparing the supporting research for each.

Etiologic Theories

The causes of the comorbidity of schizophrenia and substance abuse disorder are not well known. Over the past 40 years, several theories have been advanced to explain the relationship between substance abuse disorder and schizophrenia. Etiological theories can be categorized into groups: schizophrenia causes substance use (self-medication model), neural diathesis-stress model, accumulative risk factor model, common factor model, and affect regulation model.

Schizophrenia Causes Substance Use (Self-Medication Model).

This is one of the most researched etiological theories that suggests substance abuse disorder is the result of psychiatric problems (Khantzian, 1985; Khantzian, 1997)**.** According to the self-medication hypothesis, individuals with schizophrenia use substances such as alcohol and cannabis to alleviate the symptoms associated with their illness or side effects of the antipsychotics. The negative symptoms of schizophrenia are associated with a dopaminergic deficit in the prefrontal cortex (PFC) (Grace, 1993; Finlay, 2001). The use of psychoactive substances as self-medication causes an acute dopamine release in the PFC, thereby correcting the prefrontal dopaminergic deficit (Volkow et al., 1996; Devous et al., 2001; Gardner, 51-87, 1997; Potvin et al., 2006). Other forms of the self-medication model suggest that drugs and

alcohol are used to treat extrapyramidal symptoms caused by neuroleptic medications (Schneier & Siris, 1987).

The self-medication hypothesis has flaws. It may oversimplify the relationship between schizophrenia and substance abuse, presenting a direct causal relationship between schizophrenia and substance abuse, ignoring other factors such as genetics, environmental impacts, and pharmacological interactions. Many studies found that the patterns of substance use observed in patients with schizophrenia are like those found in other diagnoses, and the availability of different types of substances rather than the effects of specific substances determines which substance is abused (Regier et al., 1990; Mueser et al., 1992). The elevated rate of substance use disorder among first-episode psychotic patients and less substance use among deficit syndrome schizophrenia before the intake of antipsychotics further reveals flaws of the hypothesis (Green et al., 2004; Kirkpatrick et al., 1996).

Accumulative Risk Factor Hypothesis

This hypothesis proposes that patients with schizophrenia are at increased risk of developing comorbid substance use disorder due to cumulative effects of cognitive deficit, social isolation, low educational and vocational function, poverty, residence in an area with increased availability of drugs, lack of structure in daily activity, poor interpersonal skills, and association with a deviant group (Mueser et al.,1998; Anthony & Helzer, 1991; Berman & Noble, 1993; Jones et al., 2019). There is usually a positive feedback loop where schizophrenia causes cognitive and social decline, which increases the risk of psychoactive substances, which in turn worsens schizophrenia (Ng et al., 2013). Even though the hypothesis is plausible, previous reviews have suggested that the hypothesis lacks scientific validity Mueser et al.,1998; Green et al., 2007).

Neural Diathesis-Stress Model.

This hypothesis proposes that genetically- based neurobiological vulnerabilities interact with environmental factors such as substance use to precipitate the onset and relapse of schizophrenia (Fowles, 1992; Walker & Diforio, 1997). Supporting this hypothesis is the finding that the use of cannabis is associated with early-onset psychosis and relapse of psychosis (Drake & Wallach, 1989; Treffert, 1978). There are mixed findings on the temporal relationship between schizophrenia and substance use disorder (Westermeyer, 2006), but recent findings show increased use of substances among adolescents with genetic risk of schizophrenia (Brunette et al., 2018; Carney et al., 2016; Hodgins et al., 2016).

A study demonstrated a dose-response relationship between the use of cannabis and the subsequent onset of schizophrenia (Ng et al., 2013). However, the causal relationship remains controversial, especially as many users of cannabis do not develop schizophrenia, and many patients with schizophrenia do not develop substance use disorder (Wilkinson et al., 2014).

Some of the genetic vulnerabilities that interact with environmental stressors (psychoactive substance use) include the catechol O-methyltransferase (COMT) Val/Val allele,

which is linked to schizophrenia due to the associated reduction in dopamine function in the PFC (Ira et al., 2013). This COMT polymorphism (Val/Val) with adolescent cannabis use increases the risk of adult psychosis (Caspi et al., 2005). Others are interactions between polymorphisms of AKT, a serine/threonine protein kinase, with cannabis use leading to an increased risk of developing psychosis (Forti et al., 2012).

Common Factor Model

This model explains that schizophrenia and substance use disorder share the same risk factor. The risk factors that have been studied are genetics and antisocial personality disorder.

Genetic Factors

There is evidence to suggest that genetic factors play a role in both schizophrenia and substance abuse disorders. Shared genetic predispositions or genetic factors influencing susceptibility to one condition could also influence susceptibility to the other. A study revealed that a polygenic risk score for schizophrenia is associated with an increased risk of polysubstance use disorder (cannabis, cocaine, nicotine, and alcohol) (Carey et al., 2016). Genome-wide association studies (GWAS) also have provided evidence supporting a positive genetic correlation between schizophrenia and cannabis consumption (Pasman et al., 2019). Some studies that utilized a Mendelian randomization approach to determine the direction of causation between schizophrenia and substance abuse revealed the use of cannabis and cigarette smoking increases the risk of schizophrenia (Gage et al., 2016; Gage & Munafò, 2015; (Gage and Munafò, "Smoking as a Causal Risk Factor for Schizophrenia", 2015; Vaucher et al., 2017).

Three genes encoding brain-derived neurotrophic factor (BDNF), catechol-O methyltransferase (COMT), and protein kinase B (AKT) are implicated in the development of schizophrenia and substance abuse. Genetic variations of BDNF (rs6265 and rs103411) are strongly associated with schizophrenia and comorbid alcohol use disorder (Cheah et al., 2014). Other evidence shows that mutations and common gene variants that code for Netrin-1 (axon guidance molecules) and its receptor, DCC (deleted in colorectal cancer), alter adolescent mesocorticolimbic pathways. This alteration is associated with an increased risk of schizophrenia and substance use disorder (Vosberg et al., 2019). Psychiatry Genomics Consortium 2 genome-wide association study revealed a variant of the nicotinic acetylcholine receptor CHRNA5-A3-B4 gene cluster is implicated in schizophrenia and cigarette smoking (Schizophrenia Working Group of the Psychiatric Genomics Consortium, 2014). This study is corroborated by a study that revealed a genetic variation of CHRNA5 may mediate both schizophrenia and nicotine use through a shared hypofrontality phenotype (Koukouli et al., 2017). The cytogenetic study revealed that *DISC1,* previously identified as a schizophrenia risk gene, is being speculated to increase the vulnerability to opioid dependence (St Clair et al., 1990; Gelernter et al., 2014)

Primary Addiction Hypothesis (Reward Circuitry Dysfunction)

The primary addiction hypothesis proposes that substance abuse is a primary symptom of schizophrenia and results from an underlying neuropathological process that promotes positive reinforcement, motivation, and behavioral responses to addictive substances (Ng et al., 2013; Chambers et al., 2001). The dysfunctions of the glutamatergic projections from the ventral-medial prefrontal cortex (vmPFC) and temporal-limbic regions (hippocampus) and the mesolimbic dopaminergic projections to nucleus accumbens are the unifying etiology of addiction vulnerability and schizophrenia (Chambers et al., 2001; Parikh et al., 2016). A delicate balance between these projections to the nucleus accumbens regulates information processing and neuroplasticity, implicated in motivated behavior, and their disruptions lead to major psychiatric illnesses (schizophrenia and substance abuse) (Volkow, 2009; Grace et al., 2007; Kauer & Malenka, 2007). These explain substance abuse among patients with schizophrenia as a primary disease symptom with common neuropathologic causes and contradict the self-medication hypothesis that suggests the use of drugs is a secondary effect of schizophrenia. One study suggests that a dysfunction of nicotine receptors (nAChRs) causes impairment of the dopaminergic reward circuits, predisposing to the initiation and maintenance of nicotine use and subsequent development of schizophrenia (Parikh et al., 2016). Another study revealed hypoconnectivity between the regions of the brain reward circuit (BRC), especially PFC and nucleus accumbens, among patients with comorbid schizophrenia and cannabis use disorder (Fischer, 2013).

Antisocial Personality Disorder

Antisocial personality disorder (ASPD) and conduct disorder (childhood precursor) are associated with the development of a severe course of substance use disorder (SUD) and schizophrenia (Alterman & Cacciola, 1991; Cadoret et al., 1984; Hesselbrock, 1986; Penix et al. 167–96, 1984; Dingemans et al., 1998). Other studies suggest that severe mental illness (SMI) and ASPD are associated with comorbid substance use disorder (Caton, 1995; Caton et al., 1995). The association between ASPD and SUD and the increased prevalence of ASPD in patients with SMI suggests ASPD is the shared risk factor for comorbid SUD and SMI (Mueser et al., 1998).

Affect Regulation Hypothesis.

Blanchard and colleagues reported that the comorbidity of schizophrenia and substance abuse is due to difficulty with regulating negative affect (Blanchard, 2000). The personality dimensions proposed to be associated with the dual diagnosis are negative affectivity and or neuroticism and disinhibition/impulsivity (Blanchard, 2000). These personality traits are associated with lower frustration tolerance, a negative self-view, increased risk-taking, norm rejection, and increased reactivity to stress (Watson & Clark, 1984). Other studies support the negative affect regulation (reduction of dysphoric mood and anxiety) and tension reduction as the etiological cause of comorbid substance use among people with schizophrenia (Dixon et al., 1990; Dixon et al., 1991; Krausz et al., 1996; Noordsy et al., 1996). The affect regulation model

proposes that individual differences in personality traits predispose the risks of substance use among people with schizophrenia, which is in contrast to the self-medication hypothesis, which suggests the use of a substance to treat specific symptoms caused by severe mental illnesses like schizophrenia.

Conclusion

Substance abuse is prevalent among patients with schizophrenia. It usually complicates the course of psychosis, leading to significant socioeconomic, health, and legal burdens on comorbid substance use disorder and schizophrenia. Although more scientific work has been conducted in recent times on the role reward circuitry dysfunction and genetic factors play in comorbid schizophrenia and substance use disorder, they fail to fully explain the role environmental factors play in the comorbidity. More research should be conducted to understand the pathophysiology/etiological theories and clinical treatment of the comorbidity.

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Toxicity Identification in Herbal Compounds Using Artificial Intelligence by Jessenia Chan

Abstract

The use of traditional Chinese herbal medicine has been gaining popularity over the past couple of decades. This rise in popularity leads to the potential toxicity within combinations of herbal medicine. The risk of potential toxicity builds off of issues like the lack of efficiency and standardization in herbal medicinal use. To address these issues, Artificial Intelligence (AI) has been proven to tackle these issues, however, this technique has only been applied to modern biomedical drugs and not herbal drugs. As such, the current study aims to reduce this gap in the existing body of literature through the creation of an AI model using a k-nearest neighbor algorithm that successfully detects toxicity within herbal combinations.

Introduction

The usage of herbal medicine increased tremendously over the past three decades; 80% of people globally rely on herbal supplements for health care (Ekor 6). These statistics demonstrate the impact herbal supplements have globally. In a 1997 survey of US consumers who take herbal medicine, 53% of consumers thought herbal remedies were at least as effective as non-herbal remedies, and 65% considered herbal remedies safer than non-herbal remedies (Shaw 294). The positive ideology of herbal remedies demonstrates herbal medicine's global prevalence. The significant impact herbal medicine has on individuals highlights the importance of ensuring the safety of herbal medicine.

Traditional Chinese Medicine (TCM) is a medical system based on holistic principles acting on techniques, such as acupuncture, herbal medicine, manual therapies, nutrition, and mind-body therapies. Within the wide range of healing methods in TCM, Chinese herbal medicine emerged as an essential form of healthcare, with deep roots in Chinese philosophy and religion (Capodice and Chubak 3). Chinese herbal medicine places a profound emphasis on the principles of holism and the delicate equilibrium of the body, all nestled within the overarching framework of TCM (Gu and Pei 2). Holism defines the connection of everything in the body, while delicate equilibrium refers to the fragile balance of these connections that keep humans healthy. TCM aims to maintain holism and delicate equilibrium within the body.

The growing number of consumers using traditional Chinese herbal medicines makes it vital to ensure that various combinations of herbal medicines are safe. The proposed research project aims to measure the potential toxicity of combinations of traditional Chinese medicinal herbs. Toxicity is a term used to describe the negative outcome of a specific drug and it is not a specific property of drugs and chemicals (Mückter 23). Identifying toxicity is critical in herbal medicine practice because of the potential damage that may be caused to patients who use herbal medicines. The potential harm from toxicity within herbal medicine leads to the research question: To what extent can an Artificial Intelligence model assess the potential toxicity of combinations of traditional Chinese medicinal herbs used for treating Epidermolysis Bullosa Simplex?

Literature Review

Traditional Chinese Medicine (TCM), including Chinese Herbal Medicine (CHM), relies on holistic principles, like Yin and Yang and the Five Elements theory, in its approach to healing (Gu and Pei 2). The Yin and Yang theory builds on the principle of opposite forces, like light versus dark and hot versus cold. Traditional herbal medicine aims to balance these opposite forces. Meanwhile, the Five Elements theory explains how wood, fire, earth, metal, and water interact and influence each other in the body to maintain balance. If these five elements become unbalanced, herbal medicine aims to rebalance the five elements to maintain holism and equilibrium throughout the body. These two principles highlight the basis of TCM. In CHM, herbal practitioners use combinations of medicinal herbs and animal products tailored to each patient based on these holistic principles. While CHM aims to balance the opposite forces and the five elements with different combinations of herbal remedies, the combinations of herbs may produce toxicity.

The potential toxicity in combinations of assorted traditional Chinese medicinal herbs is a topic of growing concern. Herbs with complex compositions and the presence of various chemical compounds raise questions regarding their safety and potential adverse effects. Predicting toxicity is an essential component of drug discovery. The forecasting of toxicity holds a significant promise for the safe and effective use of herbal medicine. Statistics suggest that more than 30% of potential herb-drug candidates face elimination due to concerns related to toxicity (Van Tran et al. 2630). Identifying potential toxicity is crucial to avoid adverse effects from herbal medicine usage. Furthermore, researchers from The Beijing University of Chinese Medicine quote, “Promoting pharmacology and toxicology studies of Toxic Traditional Chinese Medicine (TTCM) and non-toxic Traditional Chinese Medicine (TCM) is critical for the further development and safety of TCM in clinical practice” (Liu et al. 305). This shows that further research and progress in identifying toxicity is critical to ensure the safety of herbal medicinal use.

Many studies used Artificial Intelligence (AI) in drug toxicity prediction; however, drug toxicity prediction in AI with traditional Chinese herbs has yet to be applied. The literature review explores the extent Artificial Intelligence models can assess the toxicity of combinations of these herbs, drawing insights from recent studies and research findings.

Identification of Toxicity

The evaluation of herbal combinations usually varies from doctor to doctor. The varied prescriptions are because the principles and practices of doctors are passed through generations and differ between each lineage. So, the integration of TCM principles with clinical pharmacology underscores the need for Artificial Intelligence (AI) models to assess the potential toxicity of herbal combinations to ensure results are relatively similar throughout. Due to the lack of standardization, with the implementation of AI, AI models can become a standardized tool for herbal toxicity identification. Moreover, the contamination from microorganisms and

fungal toxins like aflatoxin with pesticides and heavy metals of herbs poses an issue (Efferth and Kaina 368). Other than microorganisms and fungal toxins, contamination of herbs from external effects also raises a problem, which makes it necessary to take into account when testing for potential toxicity. Because of the intricate structure of herbal products, effects that might arise from herb-to-herb or herb-to-drug interactions are unforeseen and complicated (Tao et al.). The unpredictable interactions further exemplify that combinations of different herbs might pose risks to the patient.

Several recent studies from researchers at The University of Life Sciences in Lublin and Central South University focus on evaluating the levels of contamination present in traditional Chinese medicinal herbs. Heavy metals can produce potential toxicity when there is an excessive amount of heavy metals, such as cadmium (Cd), lead (Pb), arsenic (As), and mercury (Hg) (Kowalska). Along with heavy metals, metabolic activation can also generate potential toxicity. Similarly, Wang and colleagues (2021) from Second Xiangya Hospital at Central South University highlight this phenomenon, stating how natural products often require metabolic activation which might lead to negative toxic effects. Wang and colleagues (2021) found that enzymes like cytochrome P450s (CYP450s) primarily trigger metabolic activation, leading to the emergence of reactive metabolites generating toxicity. If the reactive metabolites are not effectively blocked by electron-rich species inside the body called endogenous nucleophiles, they can attach to proteins or DNA in cells which will trigger various toxic effects (Wang et al. 13). These toxic effects triggered from metabolic activation can include both hepatotoxicity and nephrotoxicity; hepatotoxicity is damage done to the liver, while nephrotoxicity is damage done to the kidneys. As a result, this suggests potential outcomes of toxicity are not solely dependent on types of elements. The various amounts of the specific element within the herb and different reactions that occur within herbs can affect the result of whether or not herbal combinations are toxic.

Toxicity testing is an essential factor in identifying risks associated with herbal products and avoiding harmful effects when used as medicine. The source of Chinese herbal compounds extends beyond plants to include various processing techniques that affect the traits and chemical composition of herbal materials (Han et al. 2305). Various active compounds exist within Traditional Chinese medicine, and predicting the chemical properties of these compounds is a crucial task for Chinese medicine research to further develop as potential toxicity may exist within the combinations of different chemical properties.

Possible Techniques for Deep Learning in Toxicity

Artificial Intelligence (AI) has the ability to effectively evaluate different herbal combinations. Researchers at Chonnam University created an AI model that aimed to enhance the prediction of drug toxicity, their AI model turned out to be more precise and effective in identifying potential harmful effects of compounds before human clinical trials as compared to more traditional methods of detection from doctor prescriptions (Yoo et al. 6). Similarly, researchers from Chonbuk University developed an AI model to test potential toxicity within

chemical compounds, however, they tested the model on drugs rather than on human clinical trials; their model proved to be efficient and accurate (Van Tran et al. 2639). However, to further incorporate and increase the usage of AI in toxicity prediction in drugs, it is crucial to expand the integration of AI into more perspectives. As seen in these studies, AI has the potential to identify toxicity within chemical compounds and drugs, however, it has not been applied to herbal drugs. This potential in identifying toxicity can yet be applied to the identification of toxicity within herbal medicine.

The ability of Artificial Intelligence (AI) classification models to adapt and learn echoes the potential machine learning models have to evaluate toxicity within herbal combinations. Various machine learning methods, such as random forests (RF), decision trees (DT), k-nearest neighbor (KNN), and support vector machines (SVM), reveal promising results in accurately identifying toxic compounds when used for drug toxicity prediction (Van Tran et al. 2640). Yang and Kar developed multiple AI models that used advanced machine learning algorithms, such as KNN, RF, deep neural networks (DNN), and gradient-boosting decision trees (GBDT) to predict toxicity within chemical compounds (Yang & Kar 8). It was proven that the AI models achieved superior performance across several different toxicity prediction tasks. The adoption of AI models in the context highlights the capability AI models hold to assess and predict behaviors of chemical compounds in dynamic environments; researchers can adapt the same principles to analyze the intricate nature of herbal combinations in traditional Chinese medicine, thereby assessing potential toxicity.

Deep learning techniques, like k-nearest neighbor (KNN), have been proven to be an effective machine learning algorithm for identifying the toxicity of chemicals. Swapnil Chavan and colleagues (2015) from the biochemicals department of Linnaeus University developed a computer model using KNN to predict how toxic certain chemicals are. Swapnil Chavan and colleagues (2015) divided the chemicals into two classes based on how toxic they were: highly toxic or not toxic. They used different types of fingerprints (i.e. Estate, CDK, Pubchem, etc.) to describe the chemicals' structures. After an in-depth analysis of the chemical structures, they built separate classification models for each fingerprint type using the KNN method, the KNN method calculates how similar a chemical is to its neighbors based on the fingerprints (Chavan et al. 1664). Swapnil Chavan and colleagues (2015) then tested the model using the test set to see how well they could predict the toxicity classes of new chemicals; the model correctly predicted the toxicity class for most of the chemicals; the predictions were mostly accurate when predicting long-term toxicity. For instance, 76% of the chemicals in the correctly predicted categories had predictions with less than a 10% difference from the actual values; Swapnil Chavan and colleagues (2015) concluded that their KNN model could predict both short and long-term toxicity well (Chavan et al. 1664). All in all, this study confirms the potential of KNN models to predict toxicity efficiently, which can be applied to the prediction of toxicity in herbal medicine

Epidermolysis Bullosa Simplex

Epidermolysis Bullosa Simplex (EBS) is a genetic skin disease that is shown by fragility and blistering on the skin. EBS is under a broader category of genetic skin diseases called Epidermolysis Bullosa (EB). Compared to other forms of EB, EBS is much milder as it is primarily affected on the surface of the skin, while other forms of EB are affected within deeper layers of the skin; the blistering on the skin is usually caused by the exposure to mechanical friction or trauma (Sprecher 24). Although EBS with blistering on the skin can be caused due to external factors like trauma on the skin, EBS is mainly a genetic disease. Most cases of EBS are inherited through an autosomal dominant manner, which is inheriting a single copy of a mutated gene from a parent (Mariath et al. 567). In conclusion, EBS marked by its milder clinical symptoms is an inherited skin disease.

Existing Gap in the Literature

An existing gap in the current literature is attributed to traditional herbal medicine. As seen in previous sections, current research on the identification of toxicity with Artificial Intelligence (AI) has only been applied to allopathic medicinal drugs. Allopathic medicine is a medical system that is an evidence-based system of care. Allopathic drugs are developed after multiple clinical trials and studies, so their standardization is relatively high. Meanwhile, less than 10% of herbal products are globally standardized, and the lack of standardization raises concerns about safety in herbal medicine (Ifeoma and Salawu). There is little known about the active and toxic components within herbs for the majority of herbal products. In many countries, herbal medicine has different regulatory standards when compared to allopathic drugs because of the lack of standardization in herbal medicine. The different regulatory standards raise concerns for safety and implications when used as medicine. Testing for toxicity can unveil potential risks linked to herbal usage, thereby mitigating potential adverse effects when employed for medicinal purposes. Despite some herbal toxicity identification techniques being efficient, no single approach is sufficient to predict toxicokinetics (Ifeoma and Salawu). Toxicokinetics describes how the body handles different chemical compounds. With the application of AI in toxicity identification, efficiency and standardization in herbal medicine can be improved.

Summary

The goal of this project is to determine whether or not combinations of herbs result in potential toxicity. Toxicity identification is crucial due to the growing popularity of herbal remedies. Ensuring the safety of herbal combinations is essential to address public health concerns. Additionally, it is necessary to provide accurate information to guide healthcare decisions in a largely unregulated industry because it might lead to harmful consequences for users of herbal medicine. Currently, nothing on the market can detect whether or not Chinese medicinal herbs are toxic when combined. Herbal doctors would usually prescribe herbal medication based on their expertise and judgment. However, toxicity testing has emerged as a valuable tool to identify risks associated with herbal products and avoid harmful effects when used as medicine. The researcher plans on reprocessing the data by cleaning and formatting it to

make it suitable for analysis. Next, the researcher will divide the dataset into two subsets: one for training the AI model and another for validation. Based on previous research and expert consultations, the researcher will identify relevant features and attributes in the dataset that are known or suspected to contribute to herb toxicity. Then, the researcher would use the relevant features and compile a dataset associated with the herbal compounds and toxic compounds. The model will be developed using a programming language called Python; it will be a classification-based model because the goal of the research is to decide whether a combination of herbs will be toxic or not.

Methodology Overview

The method used for this study was a create method since the researcher aimed to create an AI model. The goal of the creation of this Artificial Intelligence (AI) model is to predict potential toxicities within different combinations of specific herbs used for herbal medicine. The current method consists of three main components. The first component includes sorting and extracting open-source data sets on Traditional Chinese Medicinal herbs and toxic chemical compounds. The second component is compiling all the extracted data used to train the AI into a spreadsheet. The final component is building the AI model using the k-nearest neighbor (KNN) algorithm. The sorted data sets will be trained using the KNN algorithm.

Defense of Method

Since this study focuses on identifying possible toxicity within chemical compounds, using the k-nearest neighbor (KNN) algorithm is ideal. Biochemical researchers at the University of Sweden, Swapnil Chavan, and peers (2015) assert the effectiveness of employing the KNN approach in constructing a classification model. They note its robust ability to predict toxicity for every chemical in the dataset under examination (Chavan et al. 1670). In addition to being a strong algorithm, the KNN is a simpler algorithm to master in a short period of time compared to other algorithms like random forests (RF), decision trees (DT), and support vector machines (SVM). Moreover, opting for open data sources containing chemical compound information of herbs, rather than conducting individual toxicity assessments for each herb, is the optimal approach considering time limitations.

Extraction of Data

The first step was the extraction and analysis of data related to herbal medicines, specifically focusing on their chemical compounds and associated diseases. Data regarding herbal medicine was sourced from SymMap, an open dataset devoted to traditional herbs for herbal medicines, the data encompassed diverse categories such as targets, symptoms, ingredients, diseases, and more. However, the researcher's attention was directed towards extracting information on disease, molecular names, and herb names. Because of time constraints, the researcher chose the disease Epidermolysis Bullosa Simplex to focus on because the disease has a relatively smaller amount of herbal compounds. Next, the researcher compiled a

list of all the herbs used for treating Epidermolysis Bullosa Simplex. After compiling the list of herbs, the researcher extracted every chemical compound within each herb. The next step for data extraction and analysis is the identification of toxic chemical compounds. For the identification of toxic chemical compounds, the researcher utilized another open dataset that has a list of toxic chemical compounds. This dataset is called ToxCast. The list includes specific chemical compounds, heavy metals, alkaloids, or any other known toxins. Other than lists of chemical compounds and other chemical-related elements, the dataset included other types of data like toxicity levels however the researcher only used the name of toxic chemical compounds. After the extraction of data from these two databases, the researcher compiled the data into a new dataset organized by the name of herb as the independent variable and the herbal chemical compound name and toxic chemical compound name as the dependent variables. This new dataset will be used to test the AI model in the form of a comma-separated value (CSV) file.

Creation and Training of AI Model

The type of algorithm that was used is k-nearest neighbor (KNN), this type of algorithm is under the subcategory of classification-based models. KNN aims to forecast the appropriate class for test data by measuring the distance between the test data and every training point. In this scenario, the classes the test data would be sorted into are toxic or not toxic. The formula KNN uses to calculate the distance is by the Euclidean distance formula (*See Figure 1*). A and B represent the featured vectors also known as the different groups you are trying to classify the data point in; m represents the number of nearest plotted points you want to classify the data point in (Hu et al. 2).

$$dist\,(A, B) = \sqrt{\frac{\sum_{i=1}^{m} (x_i - y_i)^2}{m}}$$

Figure 1: Euclidean Distance Formula

By employing machine learning techniques, the model will gain the ability to identify patterns, relationships, and potential toxicity indicators within the herb combinations. The model will be developed using a programming language called Python. Python is a popular programming language that has multiple capabilities. Additionally, Python is also well known for its capabilities to create Artificial Intelligence (AI) models. Furthermore, there is an abundance of libraries within Python that are extremely user-friendly. There are libraries in Python that are specifically catered towards AI, which will ease the process of analyzing data generated from the AI model. These reasons are why the researchers decided to use the programming language Python to develop the AI model. Another tool used to complete this AI model is Google Colab.

Google Colab is an online environment that allows for the execution of code. It is especially popular for tasks like data analysis, and machine learning. The researcher chose to use Google Colab due to its flexibility in analyzing data.

Firstly, the researcher imported the necessary modules for k-nearest neighbors, including Numpy, Pandas, and Sklearn. Numpy is a library in Python used for numerical computing. Numpy offers the support for creation of arrays, matrices, and mathematical functions to analyze data structures. Additionally, Pandas is a Python library used for data manipulation and analysis. The Pandas library also offers data structures like DataFrames and Series. The data structures allow for the easy manipulation of the data. Lastly, Sklearn is a machine learning library in Python that provides tools for data mining and data analysis (*See Figure 2*).

```
[ ] import pandas as pd
    from sklearn.model_selection import train_test_split
    from sklearn.preprocessing import LabelEncoder, StandardScaler
    from sklearn.neighbors import KNeighborsClassifier
    from sklearn.metrics import classification_report
    import numpy as np
    from sklearn.impute import SimpleImputer
```

Figure 2: Importing Libraries

Secondly, the researcher printed the dataset to ensure that the Artificial Intelligence model is referencing the correct dataset (See *Figure 3*).

```
merged_data = pd.read_csv('train.csv')
merged_data.head()
```

	Herb_Name	Herbal_Compound	Herbal_Compound.1	Herbal_Compound.2	Herbal_Comp
0	Ailanthi Cortex	Quercetin	Oleanolic Acid	Beta-Sitosterol	
1	Allii Sativi Bulbus	Luteolin	Apigenin	Uridine	Palm

Figure 3: Printing Dataset

Thirdly, the researcher converted the name of herbs to a number specific to that herb name. They converted every piece of data that was not numerical into a number, this included herbal compounds and toxic chemical compounds. It is necessary to convert all non numeric data to be numerical because the k-nearest neighbor algorithm has to use numbers to calculate the Euclidean distance between the different points (See *Figure 4*).

```
# Encode categorical columns into numerical format
label_encoder = LabelEncoder()
for column in merged_data.select_dtypes(include=['object']).columns:
    merged_data[column] = label_encoder.fit_transform(merged_data[column])
merged_data['Herb_Name'] = merged_data['Herb_Name'].astype(str)
print(merged_data['Herb_Name'])
merged_data['Herbal_Compound'] = merged_data['Herbal_Compound'].astype(str)
print(merged_data['Herbal_Compound'])
```

Figure 4: Converting to Numerical Format

Next, the researcher encoded the Artificial Intelligence (AI) model to identify the feature and target variables. The feature variables are input data used to make predictions about the output. They programmed the AI model to extract the column's herbal compound to be the feature variable. The target variable is the outcome the AI model is aimed to predict. In this model, the researcher pulled out the column of the toxic compound to be used as the target variable because this research project aims to identify whether herbal combinations are toxic (See *Figure 5*).

```
# Define features and target variable
X = merged_data.drop(['Herb_Name', 'Toxic_Compound'], axis=1)
y = merged_data['Toxic_Compound']
```

Figure 5: Defining Feature and Target Variables

Afterward, the researcher programmed the Artificial Intelligence model to split the dataset into two. One for the training of the model and another for the testing of the model for accuracy. Splitting the dataset is essential because it helps determine how well the machine learning model will generalize new data (See *Figure 6*).

```
# Split data into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)
```

Figure 6: Splitting Dataset

Following the splitting of data, the researcher standardized the features of the Artificial Intelligence model. Standardization involves adjusting each feature in training data so that all the data have a mean of zero and a standard deviation of one. The reason for standardizing features is to ensure that all the features are on the same scale. Standardizing features is essential because

measuring the Euclidean distance in k-nearest neighbors is sensitive to the scale of the features (See *Figure 7*).

```
# Standardize features
scaler = StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)

# Convert y_train to a NumPy array and reshape it
y_train_array = np.array(y_train).reshape(-1, 1)

# Impute missing values using SimpleImputer
imputer = SimpleImputer(strategy="most_frequent")
y_train_imputed = imputer.fit_transform(y_train_array)
```

Figure 7: Standardization of Features

Next, the researcher created a new instance of a k-nearest neighbor (KNN) model; they trained the KNN model and set the k value to five. The k value determines the number of neighboring data points that will be assessed to classify a particular query point (See *Figure 8*).

```
# Train kNN model
k = 5  # Number of neighbors
knn_classifier = KNeighborsClassifier(n_neighbors=k)
knn_classifier.fit(X_train_scaled, y_train_imputed.ravel())
# Make predictions on the training data
y_train_pred = knn_classifier.predict(X_train_scaled)
```

Figure 8: Creating K Nearest Neighbor Instance

Subsequently, the researcher programmed the Artificial Intelligence model to generate various combinations of herbs. This part of the code generates every single possible combination of the herbs given. These combinations will be employed to predict potential toxicity levels in future analyses of accuracy (See *Figure 9*).

```
# Iterate over herb pairs
for herb1, herb2 in herb_pairs:
    print(f"Processing combination: {herb1} and {herb2}")

    # Filter data for the current herb combination
    herb1_data = merged_data.loc[merged_data['Herb_Name'] == herb1].drop(['Herb_Name', 'Toxic_Compound'], axis=1)
    herb2_data = merged_data.loc[merged_data['Herb_Name'] == herb2].drop(['Herb_Name', 'Toxic_Compound'], axis=1)
```

Figure 9: Combination of Herbs

Finally, the researcher programmed the prediction part of the Artificial Intelligence (AI) model. This prediction is part of the AI model where they had the k-nearest neighbor classifier model predict whether or not each chemical compound was toxic. So, if there exists a toxic chemical compound within a combination of herbs, the combination will be declared as toxic. If no toxic chemical compound is present within a combination of herbs, the combination will be nontoxic (See *Figure 10*).

```
    # Aggregate compound information by averaging
    aggregated_data = (herb1_data + herb2_data) / 2

    # Print shape of aggregated data
    print(f"Shape of aggregated data for {herb1} and {herb2}: {aggregated_data.shape}")

    # Encode and standardize the aggregated data
    aggregated_data_encoded = aggregated_data.apply(label_encoder.transform)
    aggregated_data_scaled = scaler.transform(aggregated_data_encoded)

    # Predict toxicity using the trained model
    toxicity_prediction = knn_classifier.predict(aggregated_data_scaled)

    # Define a threshold value for toxicity
    threshold = 5

    # Convert predicted toxicity levels to binary classification
    toxicity_prediction_binary = ['Toxic' if pred >= threshold else 'Non-Toxic' for pred in toxicity_prediction]

    # Print the toxicity prediction for the herb combination
    print(f"Predicted toxicity for {herb1} and {herb2}: {toxicity_prediction_binary}")
```

Figure 10: Toxicity Identification

Results

The results of this study suggest that the development of an Artificial Intelligence model is beneficial for the identification of toxicity in herbal combinations. The identification of toxicity from the chemical compounds produces predictions that have a passing accuracy level of at least sixty percent.

Final predictions

The AI model generated predictions by analyzing combinations of herbs and determining the presence of toxic chemical compounds. It made a total of 55 predictions based on these herb combinations. Each prediction will print out whether an herbal combination will be toxic or nontoxic. From the 55 predictions, 81% of the predictions came out as nontoxic, and 19% of the predictions came out as toxic (See *Figure 11)*.

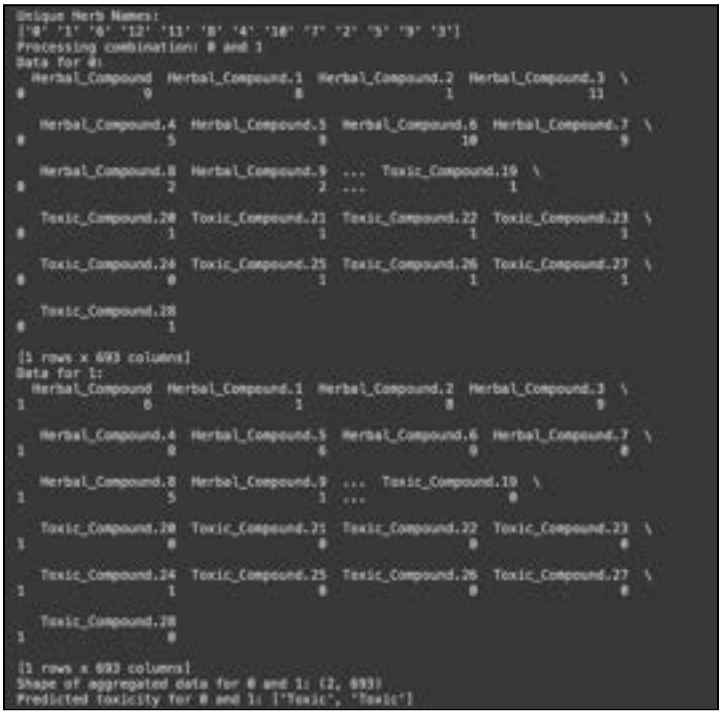

Figure 11: Results

Evaluation

When comparing the predictions to the correct outputs of whether herbal combinations are toxic, the accuracy score came out to be 98% (See Figure 12). This shows that the AI model is accurate. The macro average is a simple average of the performance metric calculated for each class in a classification problem. The macro average of the training dataset was also shown, it is within the range of 0.95 to 0.99. The weighted average takes into account the number of samples in each class when calculating the average performance of the model. The weighted average tends to lean towards classes and categories with more data, hence the average of larger classes will be bigger. The weighted average percentage came out to be within the 0.99 range which means that the overall performance of all the models across came out to be relatively high. The F1 score represents a weighted average calculated from both precision and recall. Precision is the

ratio of currently predicted cases out of all predicted positive cases, meanwhile recall is the ratio of the correctly predicted cases out of the actual cases.

```
Classification Report:
              precision    recall  f1-score   support

   Non-Toxic       1.00      0.99      0.99       173
       Toxic       0.89      1.00      0.94        17

    accuracy                           0.99       190
   macro avg       0.95      0.99      0.97       190
weighted avg       0.99      0.99      0.99       190

Accuracy: 0.9894736842105263
```

Figure 12: Classification Report

The confusion matrix is also shown to model the accuracy of the AI model. The two axes are the predicted labels and the true labels. In the matrix, 0 represents nontoxic while 1 represents toxic. When the predicted label is 0 and the true label is 0 it represents the number of correct negative/nontoxic predictions. Likewise, when the predicted label is 0 and the true label is 1 it represents the amount of wrong nontoxic predictions. Similarly, as the predicted label is marked as 1 and the true label is marked as 0 it represents the number of wrong toxic predictions. Finally, when the predicted is 1 and true is 1 it represents the amount of correct toxic predictions. By looking at this confusion matrix, it can be concluded that the majority of predictions were correct as there were few predictions in the boxes marked as wrong (*see Figure 13*).

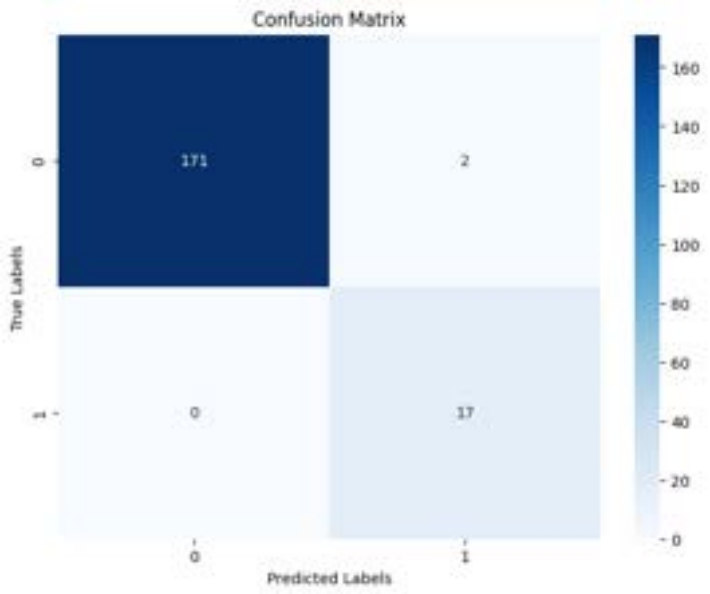

Figure 13: Confusion Matrix

Discussion

In conclusion, the toxicity identification Artificial Intelligence (AI) model used for herbal medicine has over a 90% accuracy rate. This high accuracy rate shows the potential AI has in predicting potential toxicity within herbal medicinal combinations. Furthermore, the AI model solves the issue of lack of efficiency and standardization as it has the ability to analyze and predict toxicity within two minutes. This improves standardization as it can be applied to all herbs and the method to identify whether herbal combinations are toxic are the same.

Limitations

However, it is worth noting that the research contains limitations that hinder the accuracy of the results. Firstly, the dataset used to train and test the Artificial Intelligence (AI) model missed some essential pieces of data. For instance, some of the herbs from the open-source dataset did not include a few of the chemical compounds. Furthermore, the dataset that included potential toxic chemical compounds did not account for every single toxic chemical compound. The absence of certain chemical compounds and toxic chemical compounds limits the accuracy of the AI model. The absence of the chemical compounds can also potentially explain the extremely high accuracy score, as usually accuracy scores for AI models are between the 80s to 90s range. Moreover, if the AI model is going to be used on new datasets, the new data has to be formatted in the format the original dataset was trained in because the researcher programmed the AI model to identify certain columns as targets and instance variables. If the user decides to not format their data like how the original data was formatted, necessary changes need to be made to the code. Moreover, the external effects on herbs from contamination were not taken into account due to a lack of data.

Implications/Future Possibilities

Considering how the prototype of the Artificial Intelligence (AI) model was designed effectively to identify toxicity within herbal combinations, new research can expand on this prototype. New research can modify the prototype to increase the accuracy of the AI model by accounting for more factors of toxicity within herbs. Some factors could include the toxicity level of each herbal compound and possibly external factors that can negatively affect the herb. Including these factors in the AI model will increase the safeness of the model and potentially increase the usage of herbal medicine Moreover, future research can also contribute to the user accessibility of the AI model; future researchers can build a Guided User Interface (GUI) that will increase the accessibility of the AI model to ensure the safety of herbal medicines. Currently, in order to operate the AI model, some knowledge of programming is needed. However, with a GUI, more people will be able to access the AI model further increasing the usage of herbal medicine.

If proven to be effective for the prediction of toxicity within herbal combinations, this Artificial Intelligence (AI) model will be able to help reduce the possibility of negative effects occurring from herbal medicinal use. Moreover, the AI model can be used as a more

standardized tool to identify toxicity within herbs. Ultimately, reduced negative effects and increased standardization will increase the popularity of herbal medicine, facilitating broader awareness and understanding of alternative approaches to disease treatment.

To summarize, this Artificial Intelligence (AI) model used for toxicity identification in herbal combinations aims to not only increase the safety of herbal medicine usage but to also pioneer AI in the medical field. There is great potential in the further development of this project to ensure greater efficiency and accuracy in the identification of toxicity within herbs.

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Recidivism And How To Reduce It In The American Justice System: A Social Perspective
By Kristen Alvey

Introduction

Though many may believe a person that is released from prison will never return, that is often not the case. In fact, it is quite the opposite. In recent years, recidivism (the act of returning to prison or jail) has only risen dramatically. This may be due in part to the fact that more people are being imprisoned everyday, then those returning are increasing along with it. In fact, the amount of incarcerated women alone has grown by 800% in the last 40 years (Brock, 2017). With this rise in incarceration, a new debate has begun to take shape: what must be done to reduce the rate of people returning to prison? Some may believe that it is a lost cause to try and rehabilitate and help repeat offenders, while on the other hand many believe the direct opposite. Recently, however, there has been lots of research done on different programs in order to help build a positive social environment through social programs. These social programs can work to rehabilitate, educate, and set inmates up for success upon release from prison to ensure they do not return. Through educational or social programs, recidivism rates among those in correctional facilities will begin to decline and former inmates will be able to lead successful lives outside of prison.

Reduction of Recidivism Rates and Its Benefits

Through the use of social programs, the amount of people who are recommitting crimes and ending up back in a prison facility will be able to drop substantially. With this reduction of prisoners, one commonly talked about issue in our country may be lessened: the negative and abusive treatment of inmates in correctional facilities. Many American prisons lack proper supervision, leading to severe misconduct between prisoners and employees, which typically may end in harm to the prisoners (Vera Institute, 2023). Due to this negative and unhelpful experience that many prisoners unfortunately have to go through, many inmates are not set up with the proper tools to live successful lives once released. In order to help combat this issue, prisoners must first take part in social programs in order to discourage reentering prison. Looking across the world, one can see how social programs have already begun benefitting prison systems and having beneficial effects on the prison population. In a study from the Ukraine, there were reports on how social programs to reduce recidivism were a necessary first step to revise the Ukrainian prison system as a whole (Kulikov, 2021). Kulikov further outlines the best approach to combating recidivism being, “recurrent crime prevention programs,” and, “local programs.” Through Kulikov’s research, it is clear how the social programs benefited prisoners in the Ukraine. If these same tactics were implemented in America, the benefits would speak for themselves. In fact, they have spoken for themselves. Esperian quotes Gerald G. Gaes from Florida State University as he says that programs aimed to reduce recidivism rates can have a, “significant impact,” on “large numbers of participants.” (Esperian, 2010). Statistically, the percentage of inmates who return to prison has also decreased. In fact, inmates who underwent some form of a social program or correctional education had a significantly lower recidivism rate

than the 53.7% of inmates that did not undergo a program (Hall, 2015). As recidivism rates would decrease with the inclusion of social programs in prison facilities, so would the amount of prisoners. With this reduction of prisoners, there would be more resources available to better the entire justice system with the treatment of inmates in correctional facilities.

Personal Benefits of Social Programs

Inmates who receive aid from social programs while in prison are able to achieve more and live successful lives upon their release. Though many may first think about how ex-prisoners could benefit monetarily from these programs, that is actually not where the majority of benefits stem from. Programs helped convicts better learn critical thinking skills that served them well once released (Pelletier & Evans, 2019). These skills are crucial, as critical thinking is a very important trait to make good choices and decisions. Pelletier & Evans (2019) even noted that prisoners believed these courses gave them "foundational knowledge and skills that do not become outdated." These critical thinking skills can help prisoners think about their choices to avoid ending up re-incarcerated. Additionally, these courses help inmates with personal issues such as self-confidence and self-worth. Inmates engaged in prison social programs are able to learn and feel confident in their abilities (Brock, 2017). They are able to gain confidence through learning and working with others which will benefit them when rejoining society. The social skills developed through programs make it easier for inmates to reintegrate into their communities when released, leading to more positive and helpful relationships formed for these prisoners (Brock, 2017). These communities can help prisoners build positive connections with those that can help them continue their journey away from recidivism and prison life. One prisoner named Dan commented on how these programs led to him developing a "brotherhood," that was "really strong." (Pelletier & Evans, 2019). This type of brotherhood described can be invaluable to prisoners trying to find their footing back into society, and can help them make choices that will prevent them from being institutionalized again. By introducing social programs to prisons, less people will return to prison (Davis, 2013). By not returning to prison, former inmates will be able to lead their own lives, and be able to make good choices as a part of their community. In all, social programs provide numerous benefits to inmates themselves, and are an excellent way to reduce recidivism.

Other Arguments

One possible argument against these programs is that the behavior of prisoners will not change. For instance, someone who is commonly aggressive may stay that way even though they went through a social program. Though this may be the case, research has found that though behavior and thoughts may not change, any potential re-offenses are severely delayed or even eliminated (Arbour, 2021). Additionally, social programs can be changed depending on the nature of the crime committed. For example, a person who commits a serious crime such as murder may have a stricter program applied to them. The risk needs have been evaluated in previous studies, and the results show that as long as the needs are met then the programs can still be successful (The Boston Consulting Group, 2016). Through properly tailored and designed programs, the worries of ineffectiveness based on the level of crime is avoided. Another common

worry many share is the cost these programs may pose. Though that is a valid concern as the price of these programs may run around 15 million dollars (The Boston Consulting Group, 2016), the benefits that these programs will give is much greater. With the benefits of social programs, inmates will be able to take the skills they have learned and give them back to the community, benefiting the economy and society even more.

Conclusion

Social programs are an effective way to reduce recidivism in the United States. Recidivism is a key issue in today's society that has many negative effects, so having a way to reduce this crisis is important especially today. The environment of prisons in America is commonly talked about and criticized, so finding a solution is necessary. Luckily, the introduction of social programs into institutions will help combat the issue of recidivism. Social programs provide numerous benefits such as positive impacts on prison systems as a whole and on individual prisoners.

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Understanding Student Loans and Avoiding Loan Default By Huirong Yang

Abstract

Many students rely on student loans to fund their college education, but unfortunately, a significant number of students end up defaulting on this debt. In 2023, for example, there are approximately 43.5 million Americans burdened with student debt. There are several reasons why students default on their loans. One common reason is that they borrowed more than they actually needed to cover their educational expenses. Another reason is that their post-graduation salaries are insufficient to afford the monthly loan payments. Additionally, some students fail to complete their degree, leading to default on their loans. However, by educating students about the student loan system and its policies, which are sometimes so complicated that students choose to skip, they can gain a better understanding of the consequences of their borrowing decisions. This improved understanding can help students make informed choices and avoid falling into default.

Introduction

Many students who want to achieve a higher education need to borrow money from the government or other agencies. According to the Federal Reserve, in 2022, "43.5 million Americans have student loan debt, which totals over $1.7 trillion. Each borrower owes an average of $37,787" (Rodriguez). So, understanding the fundamentals of student loans and policies for students from different countries can help students or borrowers learn more about student loans and avoid going into default. This can be done in many ways, one thing the students could do is to research the different types of student loans and find which one suits them the best.

Federal Student Loans

There are primarily two types of student loans: federal loans and private loans. The two most common types of federal loans are Direct Subsidized and Direct Unsubsidized Loans (also known as Stafford Loans). The Stafford loan is the largest federal student loan program for three reasons: its subsidized interest rate, options to defer repayment, and subsidies for interest payments. In 2009, subsidized Stafford loans accounted for about 43% of federal loan volume, and unsubsidized Stafford loans accounted for 40% (Avery and Turner). The difference between a subsidized loan and an unsubsidized loan is that an unsubsidized loan can be used for both undergraduate and graduate students. The other difference is that the size of a subsidized loan is calculated based on students' financial needs after subtracting the amount of money that families can contribute to the cost of attendance. For unsubsidized loans, however, eligibility is based on the cost of attendance minus other grants or scholarships. Moreover, unlike the subsidized loan, which will accrue interest for about half of the time when students are in school and during deferment, the unsubsidized loan requires students to be "responsible for the interest from the time the unsubsidized loan is disbursed until it's paid in full" (University of Florida). The other two types of federal student loans are the Parent Loans for Undergraduates (PLUS) program and

Perkins Loans. The government introduced the PLUS student loan program for parents in 1980. In 1958, the Federal Perkins Loan Program was created, and its funds were distributed to collegiate institutions. In the 2009-10 academic year, about 520,000 students from 1,800 institutions received Perkins loans (Avery and Turner).

Borrowers are eligible for forgiveness if they have accumulated the equivalent of either 20 or 25 years of qualifying payments. In recent years, though it might be that Texas, Florida, and California are the most populace states, students who borrowed student loans in these states received the most of President Joe Biden's debt relief through income-driven repayment (IDR). In Texas, "63,730 borrowers have been approved for an IDR discharge, nearly $3.1 billion in debt eligible for discharge. In Florida, there are 56,930 borrowers approved and over $3 billion in debt eligible, and in California, 61,890 borrowers approved and nearly $3 billion in debt eligible" (Gangitano) (Table 1). Other states with the largest numbers of borrowers approved for an IDR discharge include New York with 42,070 borrowers, Georgia with 38,590 borrowers, Ohio with 37,070 borrowers, Pennsylvania with 29,840 borrowers, Illinois with 28,450 borrowers, and Michigan with 26,980 borrowers (Gangitano) (Table 2).

	Texas	Florida	California
IDR Discharge (billion)	$3.1	> $3	< $3
Borrowers	63,730	56,930	61,890

Table 1 Borrowers and IDR Discharge from Texas, Florida, and California

	New York	Georgia	Ohio	Pennsylvania	Illinois	Michigan
Borrowers	42,070	38,590	37,070	29,840	28,450	26,980

Table 2 Borrowers in New York, Georgia, Ohio, Pennsylvania, Illinois, and Michigan.

Private Student Loans

Since 2010, private student loans have also been an option for student loan borrowers. There are many different types of private loans including degree-specific loans, international student loans, bad credit loans, state-specific loan programs, and income share agreements. Degree-specific loans are for academic programs that might take a longer time to graduate, such as medical school. Students receive a "longer grace [period] or automatic deferment while [the student completes] a residency" (Luthi). International student loans are specifically for students who do not meet the requirements for other types of private loans. Even though federal student loans will lend students money even if they have a poor or nonexistent credit history, bad credit loans are the private loans that students can apply for because of their less stringent credit

requirements; however, the interest rate will often be higher. Some states – including Rhode Island, Iowa, and North Dakota – provide private student loan agencies. These state-specific student loans are normally offered to students who study within the state, although sometimes they are provided to residents who study in another state (Luthi). For example, Rhode Island and North Dakota not only offer their residents a student loan program but also some scholarships and grants; Iowa also has several scholarship and grant programs (The College Investor). These private loans usually have a higher interest rate compared to federal student loans, so students usually take private sector loans after exhausting federal loan credit. Parents prefer private sector loans more than PLUS loans because private loans are made in the student's name (Avery and Turner). Students and their parents decide what loans the students get, and about "92.7% of all student loans come from the federal government" (Hanson).

Default

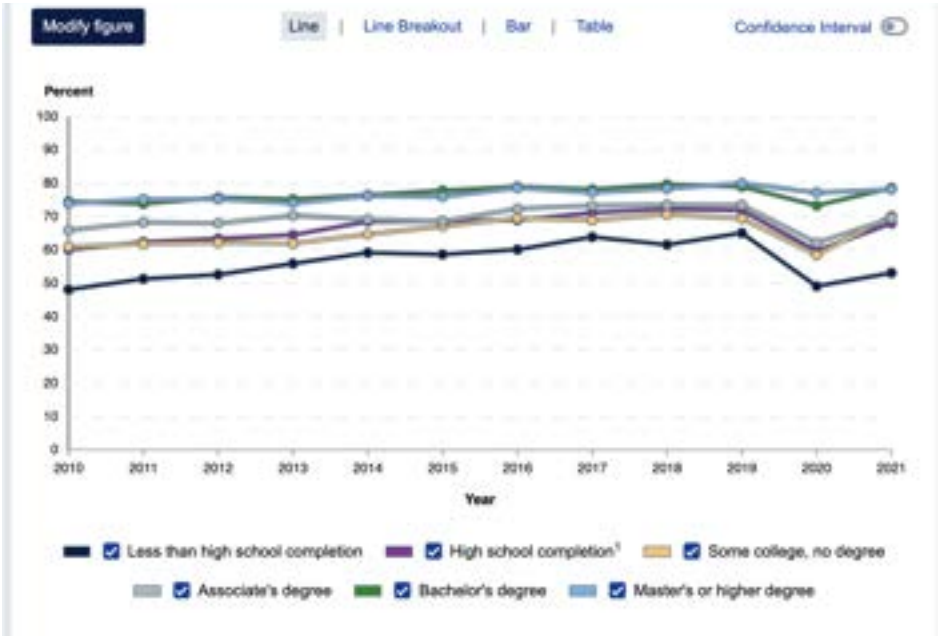
If a student loan is not being repaid for about nine months, the student loan may go into default (Johnson, CFPB). There are two primary reasons why students go into default. First, the number of undergraduate college enrollments increased from 10.5 million in 1980 to 17.6 million in 2009 (67%), while the volume of federal student loans only increased from $2.3 million in 1980 to $10.9 million in 2009 (373%, adjusted for inflation). Second, even after accounting for inflation, the cost of going to college, at both private and public four-year colleges, has almost tripled since 1980. However, federal support has not kept up: Pell Grants once covered nearly 80 percent of the cost of a four-year public college degree for students from working families but now only cover a third. That has left many students from low- and middle-income families with no choice but to borrow if they want to earn a degree. According to a Department of Education analysis, "the typical undergraduate student with loans now graduates with nearly $25,000 in debt" (The White House). Also, it is possible that students may not earn enough after graduation to enable repayment, while others may fail to graduate, limiting their income (Glater).

To avoid default, students can follow several steps. First, students should understand their loans by reading the requirements and other information provided, such as the interest rate and repayment schedule. Second, students should not borrow more than the amount that they think they can pay back; students should plan ahead of time and anticipate. The job they hope to have in the future, then they can compare their future income with the amount of money they borrow; third, if students think the monthly repayment is too much for them to keep up, they can change their monthly repayment plan. Also, for federal loans, any loans will be forgiven after 25 years which means students may not need to repay the balance of what they have borrowed (Federal Student Aid).

Understanding the consequences of borrowing student loans can be challenging because it may be difficult to see the long-term benefits of education, quantify the potential salary increase, and understand the terms of the loan. Often, student loans are a young person's first major loan. So, borrowers may lack knowledge about two things: first, students may not have a

good understanding of their future income; second, students may not understand the terms of student loans, so they will either borrow not enough or too much. They also need to consider three factors that affect the decision to invest in a college education: completing a degree, choosing a major, and their future salary.

The rate and amount of borrowing student loans varies among students going to different types of colleges. It is nearly zero for students beginning at community colleges, an average of $6,000 for students at four-year public colleges, and an average of $11,500 for students at private non-profit colleges (Avery and Turner). From 1978 to 2008, the collegiate wage distribution changed. For a male, at the 90th percentile of his high school, his career-earnings distribution would be projected to have net career earnings of $1.8 million in 1978 (constant dollars) and $2.3 million in 2008. In contrast, a student at the 10th percentile of the high school distribution would be projected to have career earnings of $603,624 in 1978 and a slightly lower outcome of $570,865 in 2008. Throughout the years, people have discovered that there are increasing benefits to attending college. Therefore, more and more people are applying to college, though some college students gain less than others, which leads to a slightly lower income. College graduates tend to be part of a stronger labor market compared to people without a college degree. This can be shown by the unemployment rate; for college graduates, it is 4.1% lower than the high school graduates' unemployment rate (Avery and Turner). The researchers do not have much evidence showing that the repayment burden for students has increased over these years. According to research in 2003, it is manageable for students to earn $25,456 each year to take 10% of it for repayment (Avery and Turner). However, the default rate increased from 6.7% to 8.8% between 2007 and 2009. For for-profit institutions, default rates are greater, reaching 15% over two years and 24.9% over three years, which means the students are probably borrowing excessively (Avery and Turner).



(NCES)

Figure 1 demonstrates the gap between the average income for different types of degrees.

International Comparison:

Countries vary significantly in their policies around student loans. For example, China raised its student loan cap by 4000 Yuan, which is about $562 U.S. dollars. In 2014, undergraduates could borrow up to eight thousand Yuan, and graduates could borrow up to twelve thousand Yuan. Now, undergraduates can borrow up to twelve thousand Yuan annually in state loans, and graduates can borrow up to sixteen thousand Yuan annually. In China, student loans are for helping students with financial disadvantages to pursue their academic ambitions. The loans are subsidized, the government covers the interest when students are in school, and students do not need to repay when they are studying. Students can have a maximum of twenty-two years to repay their student loans. The Chinese government has already given out "more than three billion Yuan and benefited more than 15 million students across the country" (Xinhua). In the United States, students need to start to repay six months after leaving college, and they need to pay back monthly for ten years with a 4.45% interest rate for federal student loans. Students can also choose to enroll in longer plans so that they can have up to twenty-five years to finish repaying their loans.

Chile limits the amount of money its students can borrow by predicting their future wages using the major that they are studying. Also, students who have a lower socioeconomic background will often have a higher default rate and a lower repayment rate due to receiving a lower-income job after graduating (Beyer, Hastings, Neilson, and Zimmerman). In Sweden, the borrowers can have a maximum of twenty-five years to repay, but normally, they will pay back all the money in twenty-two years. If they cannot finish paying back by sixty-eight years old, the remaining debt will be forgiven (Chingos and Dynarski).

The circumstances of student loans are similar in Britain and Australia, especially the repayment system. Usually, the tuition at English colleges is about $12,900, and the average total debt for a student is about $60,000, including the living expenses. Students have up to thirty years to finish repaying; if they cannot pay back after thirty years, all the rest will be forgiven. The set interest rate is an inflation rate with an addition of up to three percent depending on the student's income. In Australia, college tuition is lower than in Britain. It is about $8,300 per year, and students will typically borrow about $23,000. One difference between Australia and Britain is that no living expenses are included in Australian student loans. For their repayment, both Australian and British borrowers will only repay the loans if they have a salary above a threshold. The loans will be repaid through the tax system automatically, and the amount that a person needs to pay back is adjusted based on their income. However, in Australia, students only start to repay their loans when their income is more than $35,000, and they pay around 4% to 8% of their income (Chingos and Dynarski).

	Britain	Australia
Tuition (year)	$12,900	$8, 300
Average debt	$60,000	$23,000 (no living expenses

		included)
Ways to repay	tax system (automatically)	tax system (automatically)
How much to repay	30 years; the rest will be forgiven	4% to 8% of the income getting repaid

The panelists that *The New York Times* interviewed believed that the best type of repayment for student loans is based on students' income, has a long period of loan repayment, and the repayment being collected within the tax system. These are very similar to Australia's student loan policy, which is a reason why the default rate in Australia is very low, while in the United States, the default rate keeps increasing (Chingos and Dynarski). In the United States, about "one out of every ten Americans has defaulted on a student loan, and 5% of all student loan debt is in default" (Hanson). Also, "the federal student loan portfolio currently totals more than $1.6 trillion, owed by about 43 million borrowers" (Hahn). Policies should limit the amount that students can borrow, and adjust the value of monthly repayment like the Australian and British models.

Avoiding Student Loans

My research resulted in a few suggestions for students to think about to avoid going into default. Before borrowing money, students can research the kind of job that they want to do after graduating, and they can take a closer look at how much salary they would earn over time. In this way, they can find out what is the most prudent amount to borrow. Moreover, if the students have an expected salary, they can use this to find the best-fit university and major for themselves. If they want to invest more money in themselves, they can go to private colleges or universities. On the other hand, they can go to their state university or community colleges to keep costs lower. This can avoid borrowing more than the amount that the students can pay back eventually. After the student has borrowed the money, they could choose to do some part-time jobs when they are in school, since the repayment starts after graduating. Additionally, they could also choose internships during their four years of undergraduate school. This can help them to find better jobs, and perhaps better-paid jobs after graduating.

The government can also help with decreasing student loan default. For example, the government can provide students with more subsidized loans and financial aid. There is an IDR plan, which stands for Income-Driven Repayment (IDR) Forgiveness, and it forgives loans remaining after you make a certain number of payments over 20 or 25 years. In addition, serving in the military can cap the interest rate on the student loan (Federal Student Aid).

Conclusion

In sum, there are two main types of student loans: one of them is federal, and the other is private student loans. In the United States, paying back student loans is one of the biggest

problems in the process of the student loan. In other countries, there are many other different ways of repayment. One way that seems effective is what Britain and Australia do which is linking the repayment system with the tax system, and the loan will be automatically paid off based on their income. Additionally, having an understanding of the repayment process may also reduce student loan default and lead to more students repaying their student loans.

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Acidity Induces ETC Activity and Oxygen Production in Chloroplasts By Esat Açıkgöz

Abstract

The regulation of pH is highly controlled in the chloroplast as it is vital that there are more H+ ions in the thylakoid space compared to the stroma, since ATP synthase produces ATP using this concentration gradient. Lowering the pH of the stroma, where the pH is normally higher than that of the thylakoid space, would test the adaptability of the plant's chloroplasts and provide valuable evidence for (or against) theories of chloroplast evolution. To measure chloroplast adaptability, oxygen production was measured using a modified leaf disc assay. Leaves soaked in 0.7 mM Triton X-100 were subjected to 0.8 mM acetic acid to acidify the chloroplast stroma. It was expected that for the plant to survive and maintain its production of ATP, the electron transport chain (ETC) would work more efficiently to move H+ from the stroma to the thylakoid space, thereby oxidizing more water into oxygen. The results demonstrated that leaf discs treated with acid had an increase in oxygen production of 300% compared to the control, a very significant difference with a p-value of 0.0014 ($p<0.01$). These results indicate the chloroplast's adaptability to acidic conditions and its ability to increase ETC activity under such conditions. The findings of this research provide evidence for theories on chloroplast evolution such as the endosymbiotic theory, which states that ancient chloroplasts were prokaryotic. Prokaryotes do not benefit from the strict pH regulation in the eukaryotic plant cell and are exposed to the outside environment directly, meaning that chloroplasts in the past would have been more exposed to rapid fluctuations in pH, and would need to have a strong adaptation to changes in acidity. This vital adaptability, which likely increased the survival rate of ancient chloroplasts, is displayed in this experiment.

Keywords: acidity, thylakoid space, stroma, electron transport chain (ETC), oxygen production, endosymbiotic theory.

Introduction:

One of the most prominent debates in agriscience over the past few decades is about proper pH conditions for plants. Although it is still very uncertain what the best pH for plant life is, it is generally accepted that most plants can grow at any pH between 3.5 and 6.5 (Conover 1995; Conover 1996). However, the calculation for this range of pH is based only off the physical compartments of the plant. It is still unknown how lower pH affects chloroplasts and their production of oxygen directly, which is what this research will investigate. Chloroplasts are organelles in plant cells that are responsible for photosynthesis, and therefore the production of oxygen gas (Mathis and Paillotin 1981). They have thylakoids, which regulate pH in the chloroplast by pumping H+ ions into and out of the thylakoid (Robinson and Walker 1981; Avron 1981). When H+ is pumped into the thylakoid from the stroma, the liquid that surrounds the thylakoids, it is done so by the ETC (electron transport chain) to create a higher concentration gradient of H+ ions in the thylakoid space. When H+ is pumped out of the thylakoid and into the stroma, it is done so by ATP synthase, an enzyme that generates ATP by

pumping H+ to the outside of the thylakoid (Clark et al., 2018). As a result of the strict regulation of H+ ions in the chloroplast through these processes, chloroplasts are very dependent on controlled pH conditions, both inside the stroma and outside the chloroplast, in the cytoplasm of the cell (Hiller and Goodchild 1981). Therefore, placing chloroplasts in an acidic environment would drastically alter their surroundings, allowing for major observations on their adaptation to acidity to be made and data to be collected.

Although the process of photosynthesis relies heavily on pH control, research that contributes to our understanding of the relationship between chloroplasts and acidity is very scarce. The idea researched in the experiment was whether chloroplasts can adapt to acidic pH conditions. While we know much about the behavior of chloroplasts in their natural environment, their adaptability to lower pH is largely unknown and would be a major source of data for this field of plant science. If any adaptation is observed in the experiment, it would mean that the ETC of chloroplasts can adapt to acidic pH conditions and to compensate for the higher number of H+ ions in the stroma when its pH is lowered, can pump H+ from the stroma back to the thylakoid space faster and more efficiently.

This idea can be related to theories on the evolution of chloroplasts such as the endosymbiotic theory, which states that chloroplasts and mitochondria evolved from prokaryotic unicellular organisms. Assuming the theory to be true, chloroplasts of the past would have been more exposed to rapid fluctuations in the pH of their environment as they would not be protected by the strict pH regulation of the eukaryotic cell. The idea researched in the experiment is whether chloroplasts can adapt to acidic pH or not, so data showing adaptation would serve as evidence for the Endosymbiotic Theory, as it would suggest that adaptation to acidity is a vestigial structure of chloroplasts left from their prokaryotic ancestors for which such an adaptation was necessary. Similarly, if an adaptation to low pH is not observed in the experiment, it would serve as evidence against the Endosymbiotic Theory.

In conducting the experiment, a modified version of the leaf disc assay was utilized. Ten disks from *Lactuca sativa var. longifolia* (romaine lettuce) were cut out and soaked with a solution of Triton-X-100 to completely dissolve the cell membrane (Trejo-Tapia 2007). After the cell membrane was made soluble and permeable to H+, the leaf discs were placed in a solution of acetic acid. After placing the leaves in the acid bath, forceps were used again to place the leaves in a syringe with a solution of sodium bicarbonate (baking soda) (Steucek and Hill 1982). Once the oxygen was sucked out of the leaf discs with a syringe and they started to fall to the bottom of the syringe, they were placed in a beaker containing the same concentration of sodium bicarbonate to observe their production of oxygen over time. The amount of time that it took for each of the disks to rise was recorded as well as the total amount of leaf discs that rose after 20 minutes.

Plant Cell Wall Solubility to H+ ions

The plant cell wall is known to be permeable to small molecules and ions, which can easily pass through plasmodesmata via diffusion (Robards 1975; Robards 1976). The cell wall,

outside the cell membrane, is freely permeable to most molecules (Dey and Brinson 1984). Therefore, for this experiment, no adjustment would need to be made to the cell wall as it is already permeable to H+.

Plant Cell Membrane Insolubility to H+ ions

Unlike the cell wall, the cell membrane is insoluble to charged ions such as H+ (Cooper 2000; Betts et al., 2013). The plasma membrane is impermeable to most large uncharged molecules and all charged molecules and ions (Papahadjopoulos et al., 1972). Therefore, the cell membrane should artificially be made permeable to H+ ions for this experiment.

Lysing Plant Membranes

Triton X-100 is a chemical compound that can be used to permeabilize a plant's cell membrane without completely lysing the cell membrane. A study in which Beta vulgaris L. was exposed to 0.7 mM Triton X-100 for 15 minutes found that plant cells mildly treated with Triton X-100 released 30% of betacyanins without affecting cell viability. Furthermore, the study showed that even after permeabilization treatment, the B.vulgaris cells grew again normally and reached a biomass concentration 48% higher than that of other nonpermeabilized cells while reducing the betacyanin concentration by 25% (Trejo-Tapia et al., 2007). Therefore, using Triton X-100 at the same concentration should safely permeabilize the plant cell membranes without completely destroying them or disrupting other cell functions.

Chloroplast Inner and Outer Membrane Permeability

Another important consideration for this experiment is the permeability of the inner and outer membranes of the chloroplast to H+ ions. While the outer membrane is very permeable to most ions, the inner membrane is less permeable, but contains several transport proteins that regulate ion homeostasis, which allows for the best photosynthetic function. (Finazzi et al., 2015). Therefore, it is most likely that the increased H+ concentration of the cytoplasm would also result in an increased H+ concentration within the chloroplast, in the stroma, as is intended for this research.

Effect of Acid Rain on Plant Chloroplasts and ATP Synthase

In a study where the effect of acid rain on plants and photosynthesis was tested, it was observed that acid rain at a relatively low pH (approximately 4.5) allowed chloroplasts to retain their structure but resulted in increased ATP synthase activity, photosynthesis, intracellular H+ level, water content in rice seedlings, and overall plant growth (Sun et al., 2016). This study presents results that are significant for our study, as the acidity (achieved by acid rain) in the study was shown to increase photosynthesis and ATP synthase activity while retaining the chloroplast structure. Therefore, based on the results of this study, we can more comfortably expose the chloroplasts to moderate levels of acidity as we know that it will not significantly affect or damage them.

Endosymbiotic Theory for Eukaryotic Origin

The endosymbiotic theory has been a very controversial topic since its founding and many biologists still do not accept endosymbiosis (Schlacht et al., 2014). The theory was rejected by cell biologists by the majority from the 1920s to the 1970s, and only started gaining popularity after this time (Martin et al., 2015). During that period of time, many scientists such as Buchner stated that the theory had "gone astray", and others, such as Lederberg, stated that the theory is only a possibility and not a certainty (Buchner 1953; Lederberg 1952). Only later on toward the 1970s, was the theory popularized again after being mentioned in a paper by Lynn Sagan and another by Goksøyr (Sagan 1967; Goksøyr 1967). The theory only started gaining mass popularity and acceptance after this period, however, as stated previously, there is still much controversy about it in the scientific world. Therefore, providing evidence for or against this theory would be very important to changing or strengthening scientific views of endosymbiosis.

Materials and Methods:

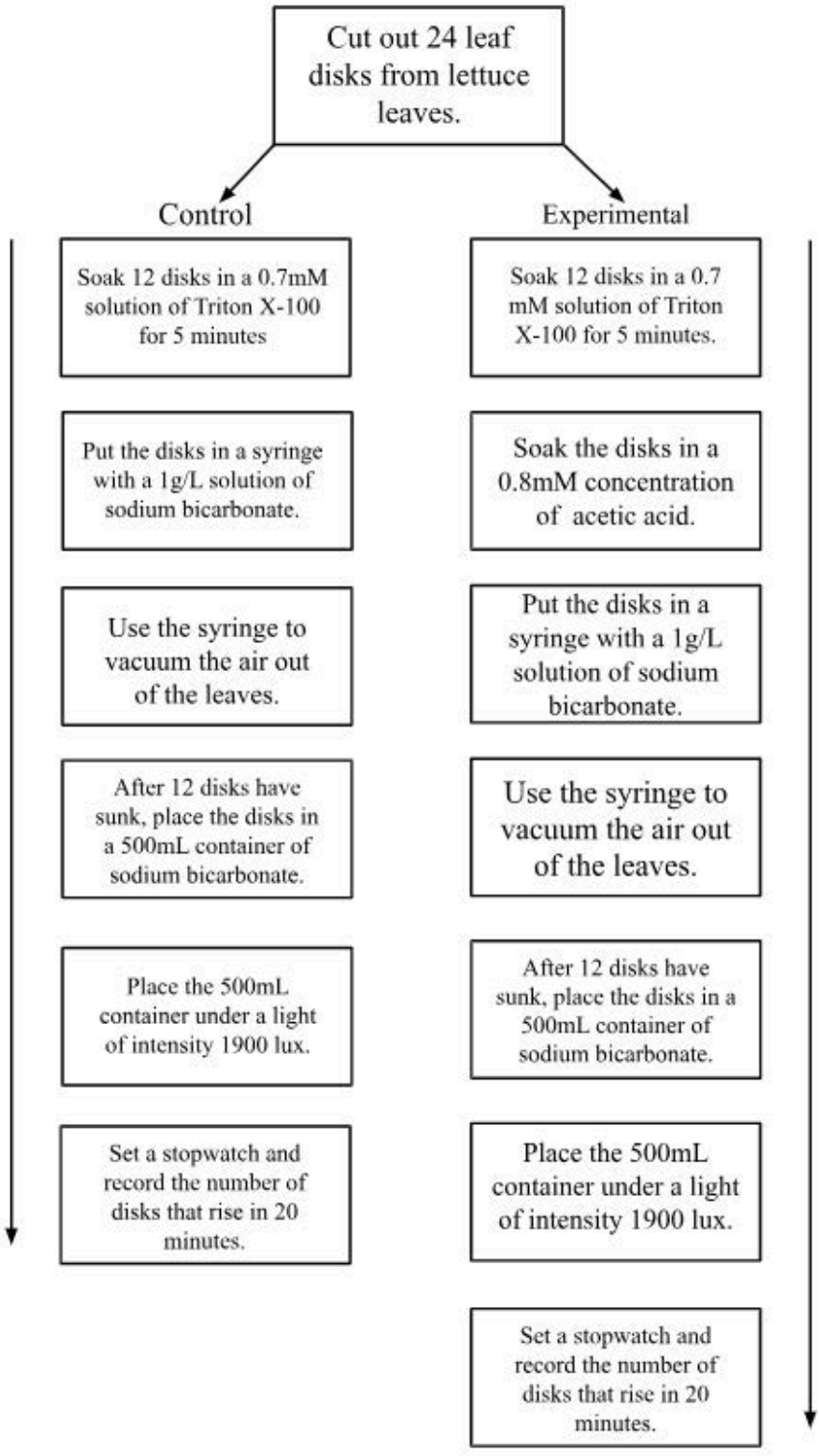

Figure 1: Visual display of the materials and methods used in this study for the control and experimental groups. The details are explained thoroughly below.

Lettuce leaves:

Fresh lettuce leaves from romaine lettuce grown in the greenhouse. When picking leaves for trials, the ones that seem the healthiest (most green) should be picked as their color indicates they have more chlorophyll and will be able to photosynthesize better.

Hole puncher:

Any model or brand of hole puncher can be used for the experiment. The diameter of the leaf discs cut out by the hole puncher used in this experiment was approximately 8 mm, which is the standard for most hole punchers and should be easy to access.

Triton X-100:

Triton X-100 was purchased from Thermo Fisher Scientific. The 0.7 mM solution was diluted initially from a 10% concentration of Triton X-100 in a 250 mL container. The leaf discs were soaked in this solution for 5 minutes.

Stainless Steel Forceps:

Standard forceps were used to carry the leaf discs from the different solutions used in the experiment carefully and without causing damage to the leaf discs (which would hinder oxygen production). The forceps should be used very gently to avoid harming the leaf discs and affecting their ability to produce oxygen. If a leaf disc was squeezed too much with the forceps, that disk was thrown out and not used in the trial.

Acetic Acid:

The acetic acid used was from Flinn Scientific. The 0.8 mM concentration was obtained after diluting the acetic acid from a stock solution of 1 M in a 1 L container. The leaf discs were soaked in this solution for 5 minutes.

10 mL No Needle Syringe:

10 mL no needle syringes were used to vacuum oxygen in the leaf discs. During the experiment, two syringes were used simultaneously by two different people to make the process faster. If the vacuuming process is unsuccessful on the first attempt and at least 12 leaf discs have not sunk, start the trial over with a fresh set of lettuce leaves and other materials.

Baking Soda:

Standard baking soda was used and mixed with water at 1 g/L to create a 500 mL solution of water containing 0.5 g of baking soda. The solution was then poured into a 500 mL beaker and used to fill up the syringes for the vacuuming process. The sinking leaf disks were placed in the beaker to be put under the light source.

Artificial Light Source:

An artificial light source with an approximate light intensity of 1900 lux was used in the experiment.

Stopwatch and Timer:

A stopwatch was used when soaking the leaf discs in Triton X-100 for 5 minutes and acetic acid for 5 minutes. A timer was used to record the amount of time that it took for each of the leaf discs to rise in 20 minutes.

Safety Materials:

Gloves and goggles were worn during the experiment. While the solutions used are very dilute, proper safety precautions should be taken.

Results

There were four trials run for the experimental and control groups, and these trials were paired together with the same sample of leaves being used for each set of trials (Figure 1). As the leaf discs rose, the times at which they rose were constantly recorded for 20 minutes. If a leaf disc was rising but had not reached the top by the end of the 20 minutes, it was not counted. At the end of this time, the total number of leaf discs that had risen was recorded.

The data collected on the rising time of each disc was organized into a table with numerical values for each of the leaf discs representing the amount of time it took for the disc to rise. In each of the experimental trials, the number of rising leaf discs surpassed 6 (see Table 1).

Minutes to rise for each disk:	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Experimental (1):	2:35	2:50	2:53	3:18	3:20	3:20	3:24	4:12	7:10	13:51	N/A	N/A
Control (1):	2:43	6:48	7:30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Experimental (2):	1:39	1:54	2:05	2:13	2:21	2:32	2:40	2:49	N/A	N/A	N/A	N/A
Control (2):	4:14	8:13	8:48	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Experimental (3):	3:07	3:54	3:54	4:53	4:55	5:14	N/A	N/A	N/A	N/A	N/A	N/A
Control (3):	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Experimental (4):	1:13	1:15	3:31	3:55	6:03	6:59	11:02	14:09	N/A	N/A	N/A	N/A
Control (4):	4:43	4:56	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Average Experimental	2:09	2:28	3:31	3:35	4:10	4:31	9:17	10:18	16:48	18:28	20:00	20:00
Average Control	7:55	9:59	14:05	20:00	20:00	20:00	20:00	20:00	20:00	20:00	20:00	20:00

Table 1: The amount of time (in minutes) that it took for the leaf discs to rise in each of the 4 trials for the experimental and control groups. Trials in which the leaf of a certain number did not rise were marked with an N/A and for usage in the average calculation, they were counted as 20:00 minutes, or 1200 seconds. As the maximum amount of time was 20 minutes and these leaf

discs did not rise at all during this time frame, their value was recorded as the maximum amount of time given for the leaf discs to rise.

One of the trials for the control group recorded no rising leaf discs, and the largest number recorded by any trial was 3 (which was recorded by Trials 1 and 2) as shown in Table 1. Aside from Control Trial 3, the other control trials recorded at least two rising leaf discs. This was followed by the 4th leaf disc in the control group, which none of the control trials recorded. Therefore, from the 4th leaf disc to the 12th leaf disk for the control group, the average time to rise was the maximum time of 20 minutes (see Table 1). Meanwhile, the experimental group's average time to rise remained very low (below 5 minutes) until the 7th leaf disc (see Figure 2).

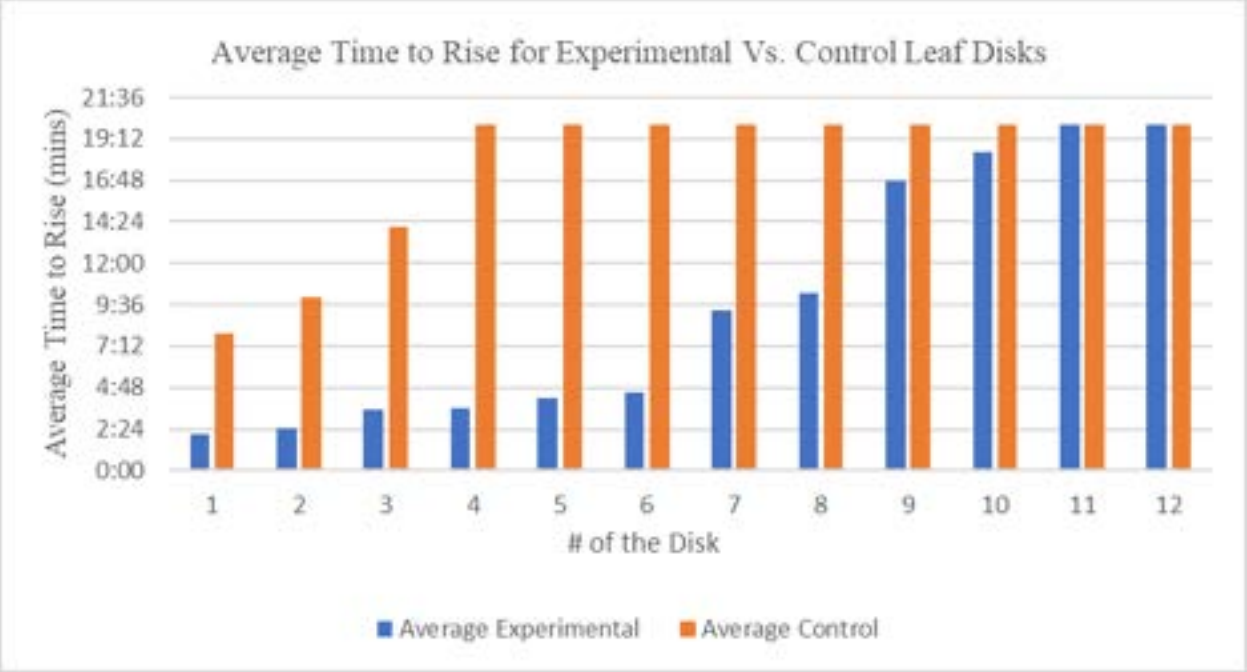

Figure 2: The average amount of time (in minutes) that it took for the experimental and control leaf discs to rise (n=4).

The experimental group's average time to rise was only at the maximum of 20 minutes at the 11th and 12th leaf discs, as none of the trials for the experimental group recorded more than 10 rising leaf discs (see Figure 2). The difference between the experimental and control groups is greatest in the first 6 disks as shown in Figure 3. The time difference peaks at 16:25 minutes at the 4th leaf disc as none of the control trials recorded rising discs at that stage (see Figure 3).

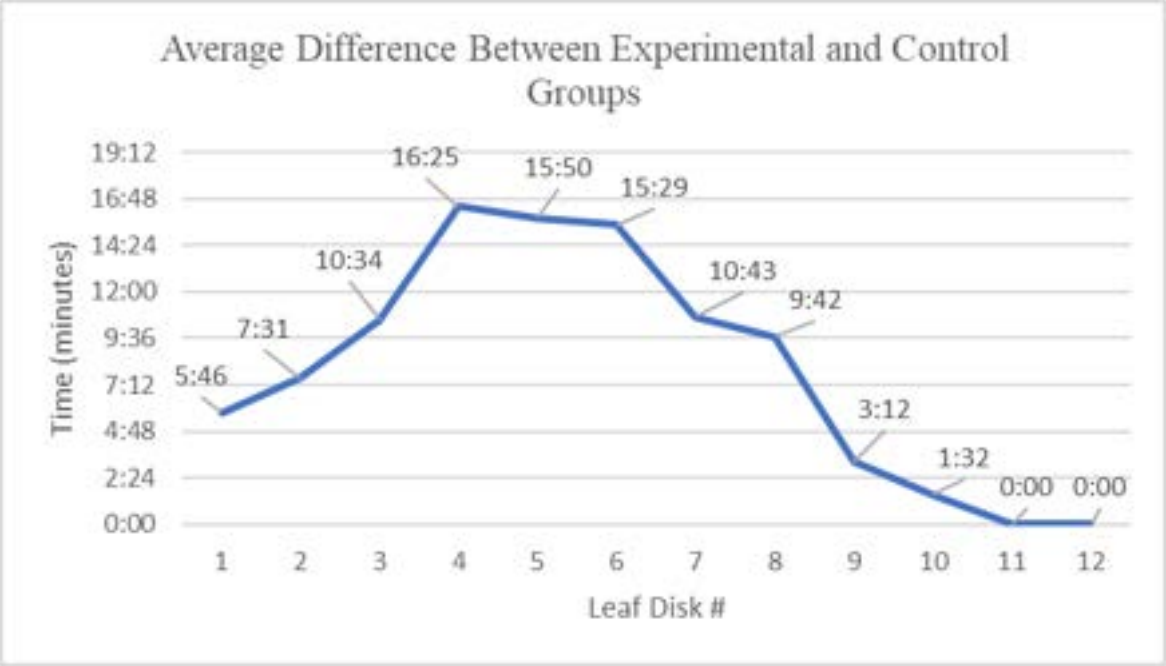

Figure 3: The difference between the average amount of time (in minutes) that it took for the experimental and control leaf discs to rise. The highest points in the graph signify the greatest amount of difference between experimental and control groups out of a total time frame of 20:00 minutes.

For the experimental group, the values of the trials up to and including the 8th disc were still relatively low, with the average time to rise for the 8th leaf disc being 10:18 minutes, as shown in Table 1. However, after the 8th trial, the graph of the experimental group showed a steep increase in the 9th and 10th leaf discs until reaching the maximum with only one trial (Trial 1) recording more than 8 rising leaf discs (see Figure 2). Overall, the greatest difference between the two data sets was recorded at the 4th, 5th, and 6th trials, with differences of 16:25, 15:50, and 15:29 minutes respectively (see Figure 3). The lowest difference between the two data sets was recorded toward the last leaf discs, with the 11th and 12th leaf discs both having a difference of 0:00 minutes. The standard deviation for the control group was approximately 1.22, while that of the experimental group was approximately 1.41. As shown in Figure 4, there was a great difference in the total average number of rising leaf discs for the control group compared to the experimental group.

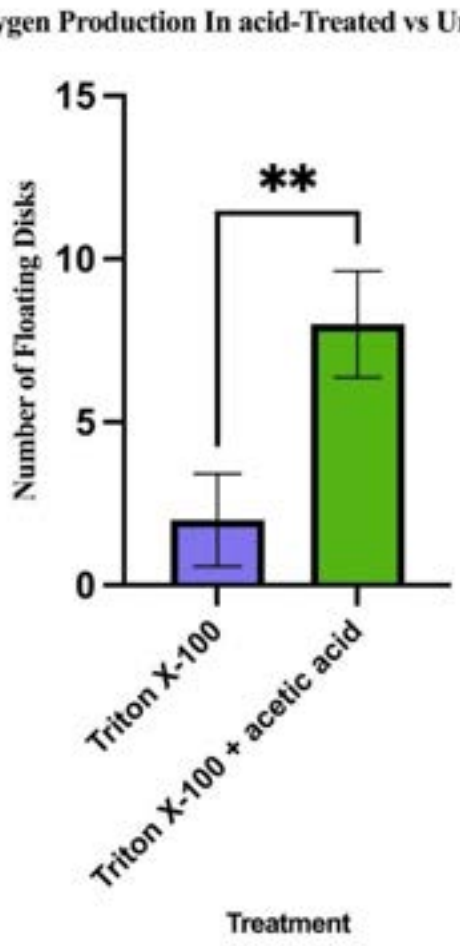

Figure 4: Difference in mean oxygen production between acid-treated and untreated leaf discs as evidenced by the number of leaf discs floating after 20 minutes (n = 4)(+/- standard error of the mean)($p=0.0014$; $p<0.01$).

The average number of leaf discs for the control group was 2 while that of the experimental group was 8 (see Figure 4). Therefore, there was an increase in oxygen production of 300% in the acid-treated leaf discs, and after an analysis of the data using a two-tailed unpaired t-test, the data obtained were concluded to be very significant with a p-value of 0.0014.

Discussion

The data recorded in the experiment are very consistent. While the standard deviation of the data was relatively high (approximately 1.22 for control and 1.41 for experimental), when paired together (Experimental 1 and Control 1, Experimental 2 and Control 2, etc.) a quick data analysis shows that the data are much more consistent than values suggested by standard deviation. The data are as follows: Experimental Trials 1-4 (10,8,6,8) and Control Trials 1-4 (3,3,0,2). When the trials were paired together, we observed that for the first trial, the experimental group recorded 10 rising disks while the control group recorded 3. For the second

trial, the experimental group recorded 8 and the control group recorded 3. Similarly, for the fourth trial, the experimental group recorded 8 and the control group recorded 2. The only trial which seems out of ordinary is the third one, as the control group recorded 0 rising disks in this trial. However, the third trial was also the trial that recorded the lowest number of rising discs for the experimental group, suggesting that the sample of leaves used in these trials simply had less chlorophyll (or some other impeding factor was present) which resulted in less oxygen production. Nevertheless, this in no way weakens the data, as it shows that whether the chlorophyll content of a leaf is high or low, the increased oxygen production caused by acidity remains the same.

These findings suggest that chloroplasts are able to adapt to acidic pH conditions, a revolutionary idea for the field of evolution. The increased production of oxygen observed in this experiment is an adaptation of the ETC to acidic conditions, in which the ETC has the ability to work faster to reestablish the disturbed pH balance between the thylakoid space and the stroma. The ETC's increased activity was present in chloroplasts of the past likely to increase their chances of survival. This is because lower pH conditions in the stroma result in less of a concentration gradient of H+, which means that ATP synthase would have more difficulty producing ATP. If ATP production decreases, this most likely means death for the chloroplast which is likely the reason that such an adaptation exists, for survival. Therefore, the findings of this experiment support the endosymbiotic theory by displaying this adaptation.

No research similar to this one had been performed before, and most of the references for this study were mainly used to provide information on the different compounds and materials used in the protocol and supply knowledge about permeability and chloroplast structure. Since the assay utilized in this experiment was a common and very well-known assay, the data produced by it were reliable. As there is more than sufficient data to show that the leaf disc assay is an effective method of measuring leaf oxygen production, modifying this well-known method to fit the goals of this experiment strengthens the likelihood of the validity of these results. This was the main reason the parameter measured in the experiment was oxygen production. While our study essentially aimed to measure ETC activity, and there are many methods of doing this, oxygen production is one of the most reliable and simple methods as there already exists a well-known protocol. This protocol, the leaf disc assay, not only allows us to collect data on the overall effectiveness of the acid (the total number of leaves risen) but also allows us to record and analyze data on the time that it took for each disk to rise. This additional data allows for a further analysis of the data and strengthens the original claim that acidity induces oxygen production (and ETC activity) in chloroplasts. In addition, while the usage of the leaf disc assay does not produce data in the form of the actual amount of oxygen produced, the focus of this research is simply to display if there would be a significant increase in the oxygen production between the acid-treated and non-treated groups. Therefore, any method of measuring oxygen production is sufficient for this study, as long as a quantifiable measurement can be taken (such as in our study, the number of rising leaf discs and times at which they rose).

There are interesting similarities and differences between our results and those observed in the study titled “Effects and Mechanism of Acid Rain on Plant Chloroplast ATP Synthase”. The main difference between our study and this study was that the study used acid rain which would be absorbed by the soil in which plants grew. This is a very different way of administering the acid, but nevertheless, the study records that the acid caused a significantly increased photosynthesis and ATP synthase activity (Sun et al., 2016). While the protocol of this research is very different than that of our study, one important shared detail is that acidity has links to increasing the rate of photosynthesis and other intracellular processes, which is a striking finding of our study. One other interesting comparison is that acid rain at an approximate pH of 4.0 in that study decreased the leaf water content, destroyed chloroplast structure, and reduced photosynthesis and plant growth, while the pH of the acid that was used in our study was approximately 3.92 (theoretical pH of 0.8 mM acetic acid), and we observed no inhibition and instead a significant increase in ETC activity oxygen production, which suggests that chloroplast structure was intact. Therefore, we can derive that perhaps the method of administering the acid has an effect on the chloroplasts and the growth of the plants, so that if acid is delivered through the leaves instead of the soil in which the plants grow, lower acidities than those identified to be the limits in the aforementioned study can be administered and result in greater and faster plant growth.

Conclusions

This research displays results that are almost counterintuitive. The most important reason for the strict regulation of pH in chloroplasts is to maintain a much lower pH in the thylakoid space compared to the stroma. Therefore, lowering this concentration gradient by decreasing the pH of the stroma would at first appear to grant the opposite of the observed results, but it instead supports the hypothesis of the experiment because of the already existing adaptation of the chloroplast, as discovered by this experiment. By causing ATP synthase to have more difficulty pumping H+ across the membrane, ATP production, and therefore, the survival of the chloroplast, is threatened. The results of this research suggest that under this threat, the chloroplast is able to adapt. The adaptation observed in the experiment can also be linked to theories of evolution such as the endosymbiotic theory, which states that chloroplasts evolved from unicellular prokaryotic organisms. If the theory is indeed true, then chloroplasts of the past would have been more exposed to rapid changes in acidity of their environment, not protected by the strict pH regulation of the eukaryotic cell. Therefore, the adaptation to acidity that we observed in the experiment supports the endosymbiotic theory.

For further research, a possible addition could be to test a new parameter, glucose production. Theoretically, increased oxygen production caused by increased ETC activity would mean that there would be an increased reduction of NADP+ into NADPH. With more NADPH, a crucial energy source for the Calvin cycle, the rate of the Calvin cycle and therefore the production of glucose could increase. With more glucose being produced, the growth amount and growth speed of the plant/crop would also likely increase. In such an event, this research can be

extended into various other fields, the most likely ones being agriculture and crop improvement, although this is out of the scope of this paper. Regardless of its future applications, the insight into this field of plant science and evolution provided by this research paves the way for many new ideas to be formed and tested and the applications of these findings are numerous.

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Uncovering Diabetes: Tips for Defeating Your Sugary Opponent By Joonha Suh

Abstract

Diabetes is a significant public health concern, affecting the well-being of individuals from a wide variety of communities. With the rising cases of diabetes, an emphasis must be placed on the health impacts and risks of this chronic condition. The report will overview the biological process of diabetes covering the mechanisms of actions of insulin, outline the risk factors of the more commonly occurring type 2 diabetes, and provide information regarding health management and treatment. This research aims to explore the relationship between dietary habits and the risks of developing type 2 diabetes. By exploring the diets of countries that are significantly directed by surging rates of health concerns, valuable insights on health management can be made through lifestyle changes.

Introduction

Diabetes, a ravaging disease affecting more than 400 million people worldwide has ceased to see significant decline over the past few years. This disease is not spread by the touch of a hand or a sudden cough, but instead either has a genetic basis or in most cases is caused by the harmful/unhealthy choices of an individual. Diabetes is common all over the world and is a contributor to the top 10 causes of death in the United States as a whole[1]. But what exactly is diabetes? It is necessary to understand that diabetes has two main types: type 1 and type 2. Type 1 diabetes, commonly referred to as insulin-dependent diabetes is mainly caused by risk factors from a patient's genetics and immune system. Roughly 10 percent of diabetes cases are related to type 1 and have no way of prevention[2]. Meanwhile, type 2 diabetes is mostly related to the lifestyle habits of an individual. The majority of diabetes cases around the world are type 2 resulting in a much higher death rate. Countries such as China and Mexico for example, have high rates of diabetes type 2[3]. This is a result of the rising obesity rates as well as subpar eating habits that have begun to grow rapidly in these countries. To grasp a better understanding of the root causes the body experiences when encountering issues from diabetes, it is important to understand the roles the pancreas, glucose, and insulin play. Glucose is a simple sugar and is needed as the most common energy source for cells throughout the body. Glucose is obtained from the digestion of starchy and sweet foods and is eventually absorbed into the bloodstream[4]. Insulin is the necessary hormone that allows for the regulation of blood sugar alongside another hormone, glucagon, and insulin allows cells to import glucose from the bloodstream to be used as fuel. Both insulin and glucagon are produced and released from the pancreas, an organ in the upper section of the abdomen, which secretes insulin or glucagon in response to changes in blood glucose (blood sugar) levels.

Type 1 diabetes (T1D) is an autoimmune disease, meaning that the body's immune system will sabotage the body itself by attacking vital organs and tissues. In T1D the immune system, whose role is to protect the body's cells and fight infections, begins to attack the

insulin-producing beta cells in the pancreas. These cells are destroyed by immune cells called T lymphocytes[5]. In the absence of insulin, glucose cannot be transported into the body's cells and instead begins to accumulate in the bloodstream. Scientists are unsure what prompts the immune system to attack insulin-producing cells but link the cause to a patient's genetics. People who have T1D are presented with the risk of high glucose levels in the blood causing harm internally. Long-term effects include damage to the blood vessels and nerves prompting risks of heart attacks, kidney issues, and strokes[4]. As opposed to T1D, Type 2 diabetes (T2D) is more common worldwide and is primarily linked to the lifestyle habits of individuals. T2D usually begins with insulin resistance which occurs when cells cannot respond properly to insulin, causing an issue with sugar concentration in the blood[6]. The pancreas naturally begins to produce more insulin to counteract the high glucose levels in the bloodstream, which is a consequence of decreased glucose transport into the body cells. However, over time the pancreas can no longer keep up and slows down the insulin-producing rate resulting in a spike in glucose levels. People who tend to have unhealthy eating habits and do less physical exercise are more likely to get T2D due to the link between insulin resistance and higher fat concentration[7]. Similar to T1D, type 2 diabetes can cause problems revolving around the nerves, blood, and kidneys in the long term. It is important to note that diabetes type 2 is largely preventable through changes to diet and exercise.

Mechanism of Action of Insulin

Blood glucose level is controlled by insulin and is heavily influenced by the ingestion of food, mainly carbohydrates that enter the bloodstream. A group of transmembrane proteins called GLUT (short for glucose transporter) has the role of transporting glucose into cells from the bloodstream[8]. There are many types of GLUT proteins, but 4 of them are the main ones, called GLUT1 through 4, each one functioning in a specific cell type. GLUT1 is expressed mainly in fetal cells and red blood cells, GLUT2 is expressed in kidney, liver, and pancreatic cells, GLUT3 is expressed in nerve cells including brain cells, and GLUT4 is expressed in fat cells and muscle cells[9]. In diabetes, GLUT1 and GLUT4 are essential transporters in the body revolving around insulin and glucose. During exercise, there is more expression in both GLUT1 and GLUT4 allowing for an increase in the insulin-stimulated uptake in muscles [8]. GLUT proteins act as a gate, allowing glucose diffusion across the membrane. Under low blood sugar conditions, GLUT proteins are not embedded in the plasma membrane of the cells, but are stored in vesicles inside the cells, as part of their membrane. Following increased blood sugar, insulin is secreted from the beta cells. When it binds to its receptor on target cells, it starts a cell signaling pathway that allows the fusion of the vesicles mentioned with the plasma membrane, resulting in GLUT proteins being embedded in the membrane, allowing for glucose to be imported into the cell[9].

Risk Factors of Diabetes Type II

Although Type 2 diabetes is composed of unavoidable risk factors such as genetics, age, and family history, changes to one's lifestyle significantly may lower the chances of developing

health issues. In the United States, obesity and lifestyle habits cause 90 to 95 percent of diabetes cases[10]. The U.S. is known for its vast fast food chains and easily accessible so-called junk food, which act as catalysts to rising dietary issues. Eating habits from consuming high-sugar and fatty foods cause spikes in blood sugar levels, and once becoming a daily routine raise the risk of developing T2D[11]. It is important to note that foods that are relatively easier to access and are cheaper in most cases come with the cost of having lower quality and being packed with sodium and sugar. Exercising strengthens the heart and allows muscles to efficiently respond to insulin and use glucose. A lack of exercise, however, can create issues revolving around the sensitivity of cells to insulin, promoting problems in the regulation of sugar levels. A common condition that results from high blood pressure is called prediabetes. Prediabetes occurs when the body's blood glucose is higher than expected, but isn't diagnosed as type 2 diabetes[12]. Although not T2D, prediabetes sets you up for future health risks if changes aren't made to directly address the problem. Roughly 96 million Americans have prediabetes and more than half are unaware they have it[12]. Despite the drastic health consequences that await if a patient is unaware of prediabetes, the condition is reversible and allows the possibility to avoid progression to T2D. Early changes such as implementing more exercise and cutting down sugar intake significantly lower the probability of prediabetes worsening. When looking at the tiny country of Nauru, which holds the highest obesity rate among all countries, the effects of lifestyle habits can easily be examined. About 40% of the population is affected by diabetes with an obesity rate of more than 50% in 2019[13]. Nauru lacks proper nutrition due to the consumption of foods such as instant noodles, and white rice, and the majority of the food is imported from western countries resulting in what some call the "Western Diet"[13]. This Western Diet consists of processed foods that are more accessible and easier to obtain than actually growing foods. The absence of a variety of fruits and vegetables has heavily affected the food availability among the citizens as proper nutrition is severely lacking in the community's diet. The disastrous consequences of a malnourished diet are evident in this island country where people are suffering from climbing health conditions. In the northern hemisphere of the world lies the country of Mexico which has seen a rise in diabetes cases over the past few years. About 14% of the population out of 128 million was affected by diabetes in 2017 and rates are still increasing[14]. Throughout the country, the number of diabetes cases and obesity rates are closely tied together. Mexico is known for its vendors and wide range of hot street food with foods such as tacos, tamales, quesadillas, and fajitas stapled in people's diets. Citizens who work long hours are more likely to consume cheap and easily accessible meals that are sold by vendors to get the energy they need[15]. However, many of the popular foods that are sold on the streets are packed with high amounts of salt and fats, which are the gateway to health issues regarding obesity and nutrition intake. It is important to note that Mexico is one of the top consumers of Coca-Cola in the world. Coke is practically everywhere and in some cases easier to find than bottles of water, causing the price to be roughly similar. In 2012, the average soda intake was about 176 liters per person, equivalent to around 500 cans[14]. Coke is seen as a default drink among people in Mexico and the popularity of such a high-sugar drink stains the average diet as diabetes rates continue to soar. Millions of people with

diabetes are burdened with financial troubles as patients are forced to pay for medications and those who are on the older side of the spectrum are left with the probability of early retirement[14]. Government and healthcare officials in Mexico are working towards spreading more awareness to the population on the dangers of the rising health conditions and advocating for healthier eating habits and exercise patterns. Based on the troubling data on the health of countries with rising cases of diabetes such as Nauru and Mexico, it is apparent that factors from dietary habits are linked to obesity and diabetes.

Health Advice to Prevent/Manage Diabetes Type II

Despite the risk of health consequences from prediabetes and type 2 diabetes, prevention is achievable through tweaks and adjustments to one's behavior and lifestyle. Keeping track of the amount of physical activity you do is crucial to lowering the risks of developing diabetes. Many root causes of health issues, not only diabetes, stem from obesity and being overweight. The CDC (The Centers for Disease Control and Prevention) recommends that people should exercise for at least 150 minutes every week and incorporate some work-intensity activities[16]. Exercise can range anywhere, from taking simple walks, participating in the gym, or even playing more extreme sports which are all beneficial to managing weight and improving overall mental and physical health. According to the American Diabetes Association (ADA), the more exercise you do the more the body is trained to process glucose and increase insulin sensitivity[17]. As we know, insulin resistance is a leading cause of prediabetes and type 2 diabetes. A form of exercise called anaerobic exercise, which involves strength training and resistance training is shown to be distinctly helpful in preventing diabetes. In anaerobic exercises, muscles become active in bursts and burn more glucose using less oxygen, compared to aerobic exercises which revolve around high oxygen consumption[18]. Muscles are made up of many fibers and it is these fibers once torn and then repaired that strengthen the body. Christel Oerum, a cofounder of Diabetes Strong, states that training that directly involves the muscles allows the fibers to tear, requiring the burning of more glucose which is important to lower the risk of developing diabetes[19]. Strength training can range from a variety of exercises from weight training, and circuit training, to intense weightlifting like bench presses and deadlifts. This type of training is recommended to be done 3 times a week and good rest is important for muscle recovery between the sessions[20]. Many adults tend to avoid working out either because of cost issues, negative views of themselves, or even difficulty managing time wisely. Free methods of exercising include taking everyday hikes/walks or even playing a sport with friends. It is important to understand that exercise is not strictly fenced off by just going to the gym and buying a membership; there are plenty of other ways to work on personal health without paying a fee. People can also hesitate to commit time to working out due to self-conflicting views on themselves[21]. Visual changes from physical activity do not happen overnight; consistency is important to achieve the changes many seek. However, changes you can see right away are blood sugar drops as well as an increase in heart rate showing that a steady inception of exercise will show clear results as time goes by. Adjusting one's daily routine to incorporate a designated time

for exercise is key to creating a healthier lifestyle. In terms of dietary habits, it is important to build a daily routine that inclines towards foods that will lead the path to diabetes prevention. Foods should be selected based on a balance of nutrients as well as to maintain blood sugar levels in the body[22]. Introducing more fruits, vegetables, and lean protein to your everyday plate is a great way to incorporate the needed nutritional value. For example, vegetables such as broccoli and spinach are packed with fiber and vitamins and do not cause dramatic increases in blood sugar levels[23]. Lean proteins such as salmon and eggs are low in saturated fat and are healthy ways to consume protein which helps stabilize blood sugar. Swapping your breakfast cereal which may contain lots of sugar for whole grain options such as oatmeal is another example of a healthier alternative. Popular staple foods in many countries such as white rice are high on the glycemic index (a measure of how foods increase blood sugar) and should be opted out for brown rice which is better for managing glucose levels[24]. Foods that contain added sugars and have high concentrations of simple carbohydrates, such as white rice and many bakery foods, are high on the glycemic index meaning that they will cause spikes in your blood sugar which is necessary to avoid to keep your health on the road to diabetes prevention. Daily consumption of processed and fast foods should be turned down due to the absurd amounts of saturated fats and calories. Drinking more water or even sparkling alternatives instead of sugary sodas are small steps that can build into a habit in terms of your diet. Popular foods such as white bread and white rice are thought of as staples in many diets around the world, but understanding that these refined grains are bad for your blood sugar is key to moving them aside. Snacks containing high-fructose corn syrup such as soda and many candies are primarily seen in all markets, grocery stores, and movie theaters which further the temptation of customers to buy. Creating a strong sense of care for your overall health will aid in resisting the urge to comply with health-threatening foods that are sold and marketed everywhere. Many popular diets that aim to avoid conditions that can lead to diabetes have the goal of lowering blood sugar while bringing in nutrients and limiting calorie intake. The Keto Diet is a typically temporary dietary plan that targets fat to be burned instead of carbohydrates[23]. Those who go with this plan tend to consume foods that are high in fat but low in overall carbs. This type of diet should be assisted with the help of your doctor or healthcare professional in the case of harmful effects since it is unnatural for the body. Another well-known diet called the DASH diet is known to benefit those who have issues with high blood pressure levels. The diet consists of eating more fruits, vegetables, lean protein, and foods that have low sodium and sugar[23]. This artisanal-based diet is known to help with insulin sensitivity and blood sugar and pressure, which are all risk factors for diabetes and other conditions such as hypertension. A more radical or extreme approach is experimenting with a plant-based diet. Being vegan or vegetarian is another alternative to switching up unhealthy lifestyles. Although a more difficult diet since animal products like meat are completely off the plate, vegans and vegetarians are commonly known to have an improvement in blood sugar levels and blood glucose concentration[23]. It is important to note that diets that involve the absence of animal products can lead to deficiencies in vitamins and

minerals such as vitamin B12, calcium, iron, and zinc. However, taking the right supplements and asking health professionals about dietary changes are ways to address this issue.

Exercises for Diabetics

Physical exercise is also key to maintaining the body to effectively manage diabetes. Increased physical activity allows for muscle cells to respond to insulin and use glucose more efficiently allowing for a lowering in the risks of developing diabetes. Aerobic exercises (involving oxygen) such as walking and running are methods to increase physical activity without the need for equipment. A clinical trial proved that walking on low intensity paired with a low-fat diet reduced the risk of diabetes by 58 percent[25]. Other aerobic exercises that can be done to get the heart to beat faster are swimming, hiking, and dancing. It is recommended by the ADA that at least 30 minutes of anaerobic exercises should be done on most days of the week[26]. Slowly incorporating more ways to get your heart pumping by climbing the stairs or choosing to walk instead of driving are small steps into a daily habit. Aerobic exercise allows for a lowering of blood glucose and increases insulin sensitivity[27]. But what if your hunger pushes your body to the limit? A form of exercise that also works towards the prevention of diabetes while being high-intensity is anaerobic exercise. Anaerobic exercise, unlike aerobic exercises, is high-intensity and breaks down glucose in the body without the need for oxygen. Aerobic exercises use glycogen from the muscles as a means of fuel causing a build-up of lactic acid. Examples of anaerobic exercise include calisthenics, weightlifting, resistance training, and sprinting. A popular form of anaerobic exercise which can easily be put into one's routine is weightlifting. Resistance training exercises such as weightlifting improves blood glucose control and allows insulin to be used efficiently[26]. When doing strength and resistance training, it is important to avoid injuries and overburdening your body. Beginners should train 3-4 times per week for benefits and to consult a trainer or someone experienced for proper form and technique.

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Gender and Mental Health: Investigating the Underlying Factors of Diagnostic Disparities
By Chloe Zhao

Introduction

Women are two to three times more likely to be diagnosed with an anxiety disorder or mood disorder in their lifetime compared to men (Albert, 2015; McLean, 2011). This phenomenon is called the mental health gender gap. It is important to understand the factors contributing to this gender gap because it may greatly contribute to improvements in mental health diagnosis and treatment. Therefore, this paper reviews potential explanatory factors behind the mental health gender gap, attempting to help the general public gain a better understanding of the causes of mental health disorders as well as the concept of mental health disparity and make efforts to address them.

Methodology

This paper is a systematic literature review conducted to gather and synthesize existing research findings on the topic of the gender gap in mental health. The review only incorporates information from sources that are peer-reviewed articles, reviews, and meta-analyses published between 2000 and 2023. The paper extracts key information from selected studies, including their main findings and conclusions. This information was organized into thematic categories corresponding to biological, sociological, and clinical system bias factors. By integrating both sociological and biological perspectives, the paper aims to adopt a multidisciplinary approach when answering the research question: Why does gender impact the rate at which individuals are diagnosed with anxiety disorders and mood disorders in their lifetime?

Gender Disparities in Mental Health Diagnosis

Males and females have a notable difference in their rate of receiving mood disorders and anxiety disorders diagnoses. Women are more likely to be diagnosed with an anxiety disorder, with the exception of Obsessive Compulsive Disorder (OCD), which is diagnosed at equal rates in adults (McLean, 2011). According to McLean's 2011 study, women are 2 to 3 times more likely than men to have Generalized Anxiety Disorder (GAD) and Panic Disorder (PD), as well as meet lifetime criteria for Social Anxiety Disorder (SAD) with more severe symptoms and greater social anxiety-related fears.

Similarly, women have a threefold increased risk of being diagnosed with a mood disorder compared to men (Rainville, 2019). Symptoms and impairments associated with these disorders also differ by gender. Men reported that Major Depressive Disorder (MDD) hampered their ability to work or study, in other words, cognitive functioning, whereas women are more likely to suffer social impairment. Women may experience symptoms such as anhedonia, sleep and feeding changes, sadness, crying, somatization, hostility, feelings of worthlessness, and comorbid anxiety (Piccinelli & Wilkinson 2000).

Biological

One explanatory factor for gender differences in mental health diagnosis relates to biological differences between men and women. Specifically, sex differences in mental health can be explained by hormone differences.

Hormonal fluctuations can reduce serotonin levels, leading to symptoms such as sadness, anxiety, and irritability (Kundakovic, 2022). During sexual maturity, the hormone levels of women fluctuate cyclically over a much more extensive range than those of men (Seeman, 1997). This higher hormonal instability among women suggests how women tend to experience more drastic mood swings, which is a key contributor to the diagnosis of mood and anxiety disorders.

Specifically, fluctuations in levels of female hormones progesterone and estrogen throughout the lifespan during the various phases of the menstrual cycle can have a significant impact on the course and severity of anxiety disorders in women. Progesterone is known to interact with the brain's neurotransmitter systems, particularly by increasing the activity of gamma-aminobutyric acid (GABA) receptors. GABAs are the brain's main inhibitory neurotransmitters. GABAs inhibit neural activity, and this inhibition leads to relaxation and reduces anxiety. Progesterone levels drop during the premenstrual phase of the menstrual cycle, causing some women who are sensitive to hormonal changes to experience increased anxiety, contributing to women's anxiety disorder diagnosis rates (Jalnapurkar et al., 2018).

Pregnancy has also been linked to an increased risk of developing mental health disorders. Estrogen and progesterone levels fluctuate throughout pregnancy and delivery (Jalnapurkar et al., 2018). Estrogen levels have been linked to changes in serotonin receptor sensitivity, which is critical for mood regulation. Again, progesterone influences GABA receptors, which play a role in anxiety regulation. As a result, hormonal fluctuations cause dysregulations of neurotransmitter systems, increasing the risk of developing mood and anxiety disorders during pregnancy and postpartum (Kumar, 2012). Women, in particular, have a 4.3% chance of receiving a GAD diagnosis in a 12-month period, which rises to 10.5% during pregnancy and 10.8% postpartum (Howell, 2001; Misri, 2015).

Beyond that, perimenopause, menopause, and postmenopausal, three stages that only occur in women, increase the risk of developing anxiety and mood disorders, thereby contributing to the disparity. Menopause is the point in a woman's life when ovulation ceases. The production of progesterone and estrogen gradually declines and ceases after menopause. During perimenopause, the sharp decline in estrogen levels increases the likelihood of developing mood disorders (Musial, 2021). Women's lifetime depression prevalence is 5.8%, but during perimenopause, women's depression prevalence is greater (Albert, 2015). Specifically, 25.99% of the participants of Li and Ma's study conducted in 2016 reported depression during perimenopause (Li & Ma, 2016). In terms of anxiety disorders, women with low anxiety at baseline have an increased chance of showing high anxiety symptoms when they are in late perimenopause or postmenopausal than when they were premenopausal, while women with high anxiety at baseline tend to continue to show high anxiety throughout the follow-up (Bromberger

& Kravitz, 2013). In terms of women's risk of developing mood disorders during and after menopause, it has been discovered that the menopausal transition impairs mood functions, resulting in a higher prevalence of depressive symptoms in the postmenopausal group than in the premenopausal controls (Amore et al., 2007).

Sociological

Moreover, sociological factors play a significant role in contributing to the gender gap, too.

Women's greater burden of mood and anxiety disorders has been attributed to their overall lower position in the socioeconomic hierarchy as indicated by their lower average earnings, occupational status, and, until fairly recently, their lower average educational background (Smith, 2018). Despite the fact that men tend to have higher socioeconomic status than women, there is substantial variation in socioeconomic status among men, for whom low income and education levels are both positively associated with depression (Inaba, 2005). Specifically, the gender wage gap is suggested to contribute to the prevalence of mood and anxiety disorders among women. Structural gender discrimination in the workplace perpetuates gender differences in opportunities and resources, ultimately manifesting itself as the gender wage gap, the average difference in earnings between women and men in the workforce, where women typically earn less than men for performing the same or similar work. A study conducted by Platt in 2016 used a propensity-score matched sample to compare women's income with that of a matched male counterpart, tested if the direction of the wage gap moderated the effects of gender on depression or anxiety. Using a sample of men and women matched for education, occupation, age, and other wage-related factors; the study results indicate that women have significantly higher odds of both types of disorders when their income is lower than that of the matched male counterpart. Conversely, when their income is higher than or equal to the matched male, in other words, when the wage gap is being alleviated, their odds ratios for both disorders decrease significantly (Platt, 2016). The test for effect modification by sex and wage gap direction was statistically significant for both disorders, suggesting how the gender wage gap may be a prominent explanation for gendered mental health disparities at the population level.

Gender socialization is another factor contributing to this disparity. For clarification, gender is a concept different from sex. Sex is the biological and physiological characteristic of males and females. Gender, on the other hand, is a socio-cultural construct. It is a result of gender socialization, the process by which individuals learn the behaviors, attitudes, and roles their culture expects of them based on their biological sex. Gender socialization has a great impact on mental health differences between males and females. It plays an important role in sex differences in fear and anxiety. This socialization process facilitates the development of different traits and cognitive factors that are related to a greater anxiety vulnerability, especially in girls and women (McLean & Anderson, 2009). For example, throughout their socialization process, girls are more likely to ask for help; they are allowed and encouraged to express their fears and worries and are more frequently oriented towards dependence, fearfulness, passivity, and

obedience. In contrast, boys are more likely to be taught to contain feelings of fear and insecurity. As a consequence of this gender socialization, anxiety levels differ between sexes; experiencing certain feelings, such as anxiety and fear, is normalized for women, and it is expected that they express them. In the case of men, the reinforcement of the suppression of certain emotions and the social expectation that they should be strong and brave might facilitate their development of useful resources to cope with those feelings (Farhane-Medina et al., 2022).

Furthermore, the stigma surrounding mental health issues, as well as gender socialization processes that discourage men from seeking help, combine to result in underdiagnosis and undertreatment of mental health conditions in men, exaggerating the gap. Females in the United States are 1.6 times more likely to receive mental health treatment in any form compared to males. Similarly, Australian women have a 14% greater chance to use mental health services compared to men (Health, 2019). This disparity is due to men's lack of help-seeking behavior, specifically characterized by a tendency to hide psychological problems and reluctance to report symptoms (O'Brien, 2005). Such tendency stems from traditional conceptions of masculinity, which depict and encourage boys and men to be assertive, competitive, and independent and influence whether or not men seek help from professionals or people in their social networks (Galdas, 2005). Men's lack of help-seeking behavior results in potential underdiagnosis, contributing to the gap. Given that men are less likely than women to seek help for mental health problems, to have symptoms that fit standard measurement tools, and to have their mental health problems identified by primary care physicians (Borowsky et al., 2000), men's rate of developing mental illness is likely underestimated, leading to exacerbated disparity.

Clinical System Bias

Although biological and sociological explanatory factors do contribute to the disparity, diagnosis biases in the contemporary medical system exacerbate the gap. According to a study conducted by Howard Garb, healthcare professionals may show gender bias in diagnosis processes, which leads to overdiagnosis of certain disorders in women and underdiagnosis in men. Specifically, the stereotypical image of women's vulnerability and men's stoicism influence case-by-case diagnosis criteria, process, and treatment decisions. This potentially exacerbates the existing difference (Garb, 2021). Moreover, the limited representation of women in clinical research and leadership positions within the healthcare system contributes to the perpetuation of gender biases in diagnosis and treatment as well. Only three decades ago, women were admitted to participating in clinical trials, and even recently, in 2022, women are only accountable for 29–34% of the participants in medical testing (Fultinavičiūtė, 2022). This limited representation perpetuates bias by providing limited and skewed data. This bias contributes to the gap because specific symptoms and responses that are not adequately studied in women due to underrepresentation may result in misdiagnosis of mental health disorders among women.

Discussion

The gender gap is a common phrase that refers to the differences between women and men, especially as reflected in social, political, intellectual, cultural, or economic attainments or attitudes. A gender gap exists in various contexts, while the mental health gender gap describes the phenomenon of women being more likely to receive a mental health disorder diagnosis (Yu, 2018). This literature review specifically zooms in on mood and anxiety disorders since they are the main types of internalizing disorders, which are the particular types of disorders women would likely suffer from (Masfety et al., 2022).

The results of this literature review highlight significant gender disparities in the diagnosis of anxiety and mood disorders while shedding light on the impact biological and sociological factors, as well as clinical system biases, have in shaping this gap. By suggesting the biological underpinnings of the gender gap, the findings also suggest avenues for targeted interventions. Understanding the role of sex-specific hormonal changes' impact on mental health leads to the development of gender-specific treatments that account for these fluctuations. Sociologically, the literature review suggests a contributing role socioeconomic inequality has on the gap. The socioeconomic disadvantage women have compared to men is a contributing factor to their relatively higher rate of receiving mood and anxiety disorders diagnoses. Additionally, gender socialization practices that normalize fear and anxiety in women lead to a greater willingness to express these emotions, resulting in higher diagnosis rates. Conversely, societal discouragement of men from expressing such emotions may facilitate the development of coping strategies but also deter men from seeking clinical help when experiencing mental health issues, and both factors combine to contribute to lower diagnosis rates among men.

Hence, to address the mental health gender gap, it is essential to adopt a multidisciplinary approach that combines biological and sociological solutions. Targeted interventions should focus on treating sex hormone-induced symptoms and addressing the impact of gender socialization.

This literature review has a limitation. The oldest source used in this paper dates back to 2000. Acknowledging that mental health research is a dynamic field that continues to be shifting and evolving, relying on sources that date back to more than two decades ago may have conclusions that do not fully align with current knowledge in the field of psychology. One of the most visible examples is the release of the most recent version of the Diagnostic and Statistical Manual of Mental Disorders (DSM). DSM is the handbook used by healthcare professionals as a guide to the diagnosis of mental health disorders. DSM-4 was published in 1994, while DSM-5 was released in 2013. Since the sources used in the literature review range from 2000 to 2023, the diagnostic criteria utilized span two different versions of the DSM. Changes to the DSM have an impact on the definitions, classifications, and diagnosis criteria for various mental health disorders. As a result, studies conducted before 2013 using DMS-4 might not be directly comparable to more recent research that uses DSM-5 criteria.

Conclusion

To summarize, the gender gap in mental health is influenced by a variety of factors ranging from biological ones to social ones. Biologically, fluctuations in the hormones estrogen and progesterone both lead to a heightened risk of developing mood and anxiety disorders. Pregnancy and the menstrual cycle both induce hormonal fluctuation and lead to women's larger risk. Sociologically, socioeconomic disparities, gender socialization, and stigmas around mental health bring about the difference as well. In addition, biases of the clinical system, including diagnosis bias and limited representation of women in clinical research, both lead to misdiagnosis, exacerbating the disparity.

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The Effect of Repeated Exposure to Clinical Alarms on Stress in Nurses By Zachary Zou

Abstract

Within this literature review, the extent of the effect of repeated exposure to clinical alarms on the stress of nurses are evaluated and studied. The sources of stress are examined by focusing primarily on the critical issue revolving around alarm fatigue, or the tuning out of alarms by nurses, is explored. Furthermore, the causes of alarm fatigue, false or nuisance alarms and improper alarm management, are discussed using nurse perceptions, given through survey and questionnaire-based studies. Through the research, it is clear that repeated exposure to clinical alarms of nurses lead to stress and fatigue because of responding to insignificant alarms, dealing with the constant noise of clinical alarms, and inefficient alarm management. In the future, it is advised that clinical alarm systems should be reevaluated to lower the amount of false alarms as well as alarms in general to create a better working environment for nurses for the betterment of both their health and their patients.

Introduction

The ICU, or the intensive care unit, is an incredibly important section of care within hospitals where patients who require critical medical care are given specialized treatment. Specifically, the ICU is the specialized hospital units that are equipped to sustain the lives of critically ill patients. ICUs continuously monitor patients at high levels and provide intensive, organized nursing care to support their recovery. This is achieved through the use of advanced medical equipment, such as ventilators, cardiac monitors, and intravenous infusion pumps, as well as by having a dedicated team of critical care physicians, nurses, and other healthcare providers who are trained to manage complex, life-threatening conditions. Said nurses in ICUs are constantly subject to high-stress situations. A study conducted in Pune City, India found that 68.29% of ICU nurses were reported to be stressed (Kumar et al., 2016). These rates of stress are found during critical occupational activities such as hospice care, running complex technology, and intense procedures. In addition, ICU nurses regularly have 12-hour shifts which can exaggerate stressors in their workplace and lead them to suffer from the various problems related to said occupational stress which can include burnout, anxiety, and depression (Mealer et al., 2017). Because of their profession, the mental health of ICU nurses is not only a pervasive issue among them, but it is also a matter of great concern for their patients who rely on them to receive the proper care they desperately need.

Therefore, any additional stressors that could affect ICU nurses and other medical professionals should be scrutinized to decrease their effect, so that both nurses and their patients can be in their best condition. An increasingly alarming stressor that has permeated its way into ICUs is clinical alarms. A clinical alarm is defined as an alarm system that is integrated into medical equipment and monitors which is triggered by physiological changes in a patient. Some common examples of clinical alarms are monitors, ventilators, infusion pumps, and patient beds. Although they are exceptionally useful and necessary to an ICU, an issue arises from the sheer

amount of clinical alarms that appear in ICUs. Shockingly, 150 to 400 alarms are sounded per shift per patient (Sendelbach et al., Funk et al., 2013). Since nurses usually care for far more than one patient, that statistic can be multiplied. In addition, nurses spend 35% of their shift responding to alarms. This sensory overload as well as the issues stemming from it substantially impact nurses in ways that impede on their performance and levels of stress.

Alarm fatigue

Due to the multitude of alarms sounding constantly in an ICU (intensive care unit), an increasingly prevalent issue is alarm fatigue. Alarm fatigue primarily affects nurses, and it is used to describe when medical professionals like nurses become desensitized to alarms in their workplace because of the amount of alarms that sound constantly. As previously stated, the average amount of alarms per patient in a nurse's shift ranges from 150 to 400 (Sendelbach, S., & Funk, M. 2013). A study in Korea found that 45.5 alarms sounded per hour per patient. This sheer amount of noise in the nurse's environment can lead them to inadvertently blocking out important calls to action (Cho et al., 2016). In addition, 35% of a nurse's working time is dedicated to responding to alarms, the sensory overburden caused by this is incredibly hard to avoid within the current alarm management systems in ICUs around the world. The main cause of alarm fatigue can be attributed to false alarms, inappropriate alarms-setting ranges, and the overuse of patient monitors. The most problematic of these causes are false alarms. This is incredibly dangerous as a nurse could miss an alarm entirely or delay their response to an urgent issue. This endangers patients and causes great stress within nurses. In one instance, a nurse did not respond to the low heart rate alarm which led to the patient's death. The Centers for Medicare and Medicaid Services investigated the incident and found that the nurse did not recall hearing the alarm due to alarm fatigue (The Joint Commission, 2013).

Alarm fatigue can be dangerous to both the patient and the nurse. In response, questionnaires have been developed to gain insight on the amount of alarm fatigue found within nurses and how it affects them. This allows researchers to gather quantitative data. One such questionnaire is based on the HTF (Healthcare Technology Foundation) studies. It prompts nurses to rank statements from 1 to 9 depending on how they inhibit the effective management of clinical alarms. On average, the score given to difficulty in hearing an alarm was a 4.18. Which demonstrates that although it may not be the most glaring issue in alarm management, it is still an important factor on the path to better alarm management in the future. Furthermore, nurses have been asked to give qualitative data through both statements as well as open and multiple choice questionnaires. Through these questionnaires, it was concluded that 93% of nurses agreed that fatigue caused by alarms lead to silencing or ignoring them (Funk et al., 2014). Sadly, it is not a skill that comes through time as a study in Ireland concluded that the long-term experience and education of a nurse did not improve their ability to combat alarm fatigue (Casey et al., 2018, 2018).

Although these questionnaires provide valuable insight on how nurses both perceive and are affected by alarm fatigue, their attempts at evaluating the amount of alarm fatigue in nurses has been unreliable. The research found that 69.4% of Korean nurses had moderate to high levels of alarm fatigue and the average rating for alarm fatigue was 24.3 out of 35, but the results may not be valid. This is due to the simplicity of the polls implemented combined with the limited range of questions posed to interviewees. Another research study from Iran developed a high-level questionnaire to assess alarm fatigue in nurses. The tool used turned out to be valid and reliable (Torabizadeh et al, 2017.) due to their nuanced approach to distinguish the common stressors related to nursing (long hours, personal responsibilities, etc.) from alarm fatigue related effects. Despite this, further research should be conducted as alarm fatigue continues to be a threat to nurses and their patients. Creating a reliable tool to be able to assess the amount of alarm fatigue in a nurse is necessary to improve the quality of ICUs around the world. With these possible improvements to alarm management, hazardous situations revolving around alarm fatigue can be avoided.

False Alarms

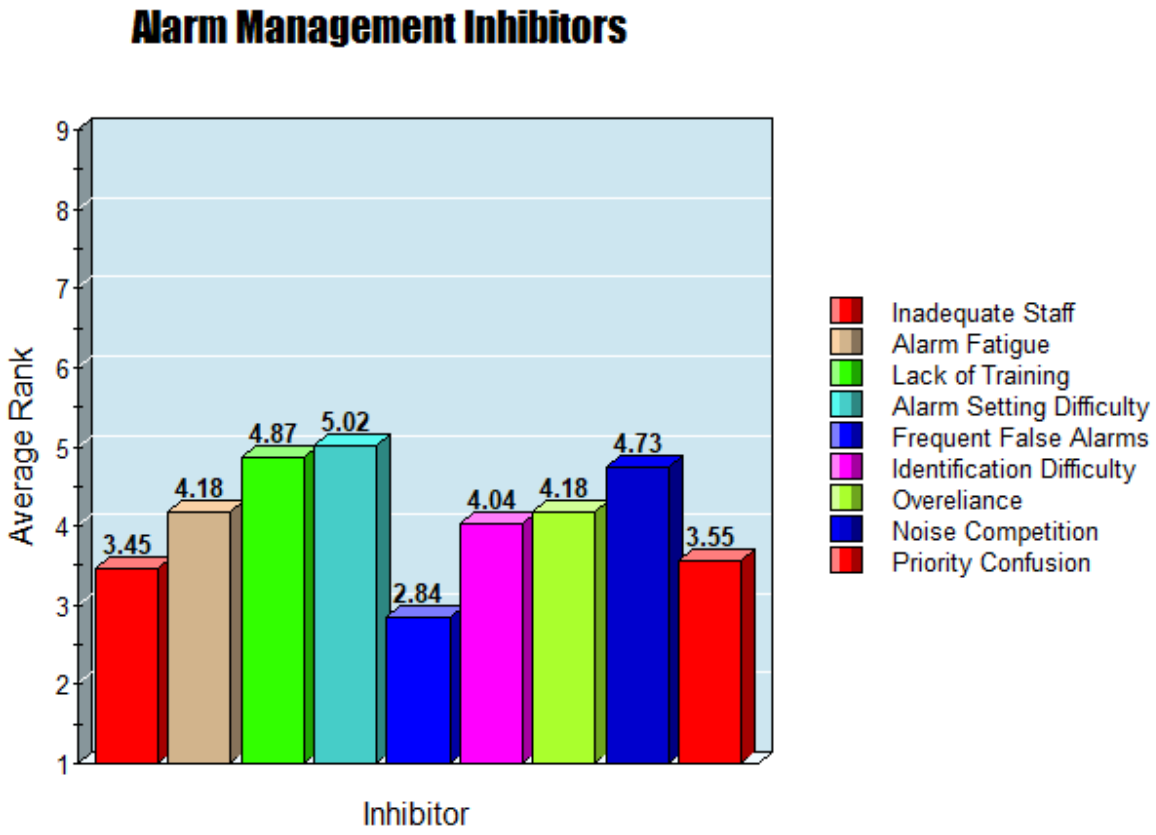
With the absurd amount of clinical alarms in ICU, it is impossible for every single one of the alarms to be significant. In fact, many alarms are no longer useful to nurses and other medical professionals due to high rates of false alarms. False alarms are defined as alarms without clinical significance. These rates are so high that in one study, signals that are false or clinically insignificant amounted to even 85-99% of all alarms (Purbaugh T, 2014). In addition, another study found that in the 2,184 clinical alarms that were counted in 48 hours, 1,394 alarms were categorized as false alarms, which means the false alarm rate was 62% (Cho et.al., 2016). These frequent false alarms may cause nurses to regard significant alarms as false and lead to alarm fatigue thus failing to respond properly. It may also make an alarm system less reliable and may cause nurses to completely reject some alarms which could set a terrifying precedent. Therefore, it is essential to effectively manage medical device alarms and develop good interventions that can reduce false alarms. A further study suggested that 98% nurses inappropriately turn alarms off, the main reason for this being the loss of confidence in the system due to the unacceptably high false alarm rate (Sowan et al., 2015). This would imply that false alarm rates make clinical alarm systems unwieldy and untrustworthy. The respondents also noted improperly set thresholds and inaccurate sensors were the cause of the false alarms which led them to relinquish the systems which compromises monitoring. This can lead to terrible outcomes for the wellbeing of patients. One study found that 31% of nurses confirmed adverse patient events related to alarms at their facility occurred within the past two years (Peterson et al., 2017). Furthermore, the vast majority, from 76-98% of nurses, commented that these nuisance alarms are highly disruptive to patient care (Sowan et al., 2015, Cho et al., 2016). As a source of alarm fatigue along with a myriad of other frustrations, false or nuisance alarms are an issue which should be addressed as clinical alarm systems are improved upon in the future.

Methodology

To find resources for this paper, Google Scholar was used to find scholarly sources in the form of scientific literature which included primary studies, scientific journals, and literature reviews. The keywords used included “nurses”, “clinical alarms”, “alarm fatigue”, and “alarm management”. The goal of the research was to answer the question of the extent to which alarms caused stress in nurses. In addition, another aim was to identify and understand the sources and conditions which lead to alarms causing stress in nurses. To do this, nurse feedback and opinions in the form of questionnaires were greatly relied on as well as statistical data. Data from four research papers (Sowan et al., 2015, Cho et al., 2016, Peterson et al., 2017, Casey et al., 2018, 2018) using the HTF model of questionnaires was examined and compared. The main focus of my research was on alarm fatigue and false alarms.

Nurse Perceptions

Recent nursing surveys for nurses in the ICU have revealed critical concerns surrounding the perceived issues in clinical alarms. Quantitative data collected through questionnaires were compiled from four studies (Sowan et al., 2015, Cho et al., 2016, Peterson et al., 2017, Casey et al., 2018, 2018) using the HTF model of questionnaires. In each questionnaire, nurses are asked to rank issues that inhibit proper alarm management from 1-9. The least important issue was inadequate staff which averaged a 3.45 between all studies. This can be explained by nurses showing inherent bias by perceiving themselves as adequate. Difficulty in hearing alarms, or alarm fatigue, scored a 4.18. Lack of training averaged a 4.87, and the most important issue on average was difficulty in setting alarm properly which averaged a 5.02. Being considered as the most important obstacle in alarm management, training and difficulty in setting alarms are issues that are important to consider. In addition, there may be a causation between the two. However, it could also be that the clinical alarms are so confusing to set that even with proper training, there would still be difficulties maneuvering the systems.



In addition, qualitative data was gathered in the form of personal statements between the same studies. By cross analyzing each study, it was found that although 58-89% of nurses stated they regularly use and change the clinical alarm systems for their patients, only 35% were aware of hospital policies designating alarm management as their responsibility. This could be due to alarm management being often considered as a lower priority compared to other responsibilities. It was also found that 94-100% of nurses agreed that distinct audio and visual indicators should be implemented to consider different clinical alarm priority levels. This would be a great step in alarm management as it could even lower alarm fatigue as the change in alarm audio and visuals could add variety and make them more noticeable to an overstimulated nurse. These survey results emphasize the need to revamp the current ICU alarm systems by implementing alarm management policies, training nurses on alarm setting, and implementing different sounds and visuals to indicate criticalness.

Although alarm related stressors could more than likely be the cause of heightening levels of stress among nurses, there are many other factors, which could be either nurse related or not, that could factor into this trend. For example, staffing levels and shift patterns could impact this. The nursing profession continues to face shortages due to a lack of potential educators, high turnover, and inequitable workforce distribution. These pressures combined with incredibly long,

sometimes 12 hour shifts, could very well be a larger contributing factor to the rise of alarm fatigue and stress instead of the misuse of clinical alarms.

Conclusion

Frequent alarms, compounded with rampant false alarms lead to both alarm fatigue and stress among nurses. Responding to alarms only for them to be non-important causes frustration and dissatisfaction among nurses as this decreases the quality of care they can provide to their patients. In addition, the effect of false alarms as well as the sheer amount of alarms lead to alarm fatigue, a dangerous state in which a nurse can completely miss a crucial alarm. This can lead to disastrous outcomes for both patients and nurses. In the future, alarm systems should be reworked to include less alarms as well as more distinguishable alarms to minimize the effect of alarm fatigue. In addition, alarms should be better optimized to allow for false alarm rates to decrease. Through better alarm management, stress in nurses can hopefully be fixed so that ICUs can be safer and more efficient. In conclusion, repeated exposure to alarms combined with rampant false alarms in the workplace causes great stress within nurses.

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Advanced Oral Rehydration Therapy Integrating Bioengineered Thioredoxin Enzymes to Combat Vibrio Cholerae Infections By Anika Kothari and Chloe Dai

Abstract

Cholera, a diarrheal illness caused by Vibrio cholerae, poses a significant global health threat with millions of cases and thousands of deaths annually. Current methods of combatting cholera, including antibiotics, vaccines, and Oral Rehydration Therapy (ORT), have made strides in combatting cholera but face challenges in accessibility and efficacy. Looking towards the future, we propose an innovative two-step approach to enhance Oral Rehydration Therapy (ORT). Our technique involves a rice-based carbon source and the integration of bioengineered Thioredoxin targeting the critical disulfide bond of the cholera toxin, providing both immediate treatment and long-term immunity. Critical advancements in packaging, enteric coatings, and enzyme modification are crucial for the success of enzymatic oral rehydration packets.

Present Technology

Cholera is a diarrheal illness caused by infection of the intestine from the Vibrio (V.) cholerae bacteria. V. cholerae is typically found in water and food that have been contaminated by the feces of people previously infected. The bacteria thrive in brackish rivers and coastal waters. Researchers estimate that there are up to 4.0 million cases of cholera annually, including 21,000 to 143,000 deaths worldwide. Cholera has reached pandemic levels 7 times since it originated, making it vital to find a more effective treatment to minimize its death toll. Current methods of combatting cholera include antibiotics, vaccinations, and Oral Rehydration Therapy (ORT).

When used to treat cholera, antibiotics reduce the severity of illness and prevent transmission to others. Effective antibiotics to treat cholera are doxycycline, azithromycin, and tetracycline. However, common V. cholerae strands O1 and O139 have developed resistance to most antibiotics, so it is recommended to only use antibiotics where these strands are not prevalent. Furthermore, allergic reactions are common with antibiotics, and other adverse side effects also have great impacts on already sick patients.

Currently, WHO has approved 3 oral cholera vaccines (OVCs) Dukoral, Shanchol, and Euvichol. They have displayed effectiveness when paired with other treatments of antibiotics or ORT. OCVs primarily induce mucosal immunity, which is mediated by antibodies, specifically immunoglobulin A (IgA), targeting the pathogen. These antibodies are specifically designed to recognize antigens like the O1-specific polysaccharide and CT. Unfortunately, due to their short period of useability and high costs, vaccines (especially Dukarol) are intended more for travelers than populations in epidemic regions.

The most common method currently to manage cholera is oral rehydration therapy. Oral rehydration therapy (ORT) is the administration of an oral solution containing a carbon source and electrolytes and is currently the predominant treatment for cholera. V. cholerae infections cause the intestinal epithelial cells to lose great volumes of critical electrolytes. Typical ORT

prescribed by the World Health Organization (WHO) contains vital ions of sodium, chloride, and potassium alongside glucose which acts as a carbon source. However, glucose can also increase the production of cholera toxin (CT), an AB5 multimeric protein complex secreted by the bacterium Vibrio cholerae. CT exacerbates the severe symptoms of cholera, so an alternate carbon source of rice has recently been implemented, reducing stool volumes by 36%. A comparison between glucose and rice ORT illustrated reduced episodes of vomiting, a decrease of the stool volume, and a shortened recovery time associated with rice.

Although ORT is currently effective in treating the effects and symptoms of cholera, it does not address the risk of reinfection. ORT focuses on mitigating the water loss and diarrhea induced by cholera, however if a patient contracts V. cholerae for a second time their course treatment remains unchanged. It minimizes the symptoms and duration of the illness but is limited as it does not target the underlying infection, and with increasing rates of reinfection, building immunity in patients is critical.

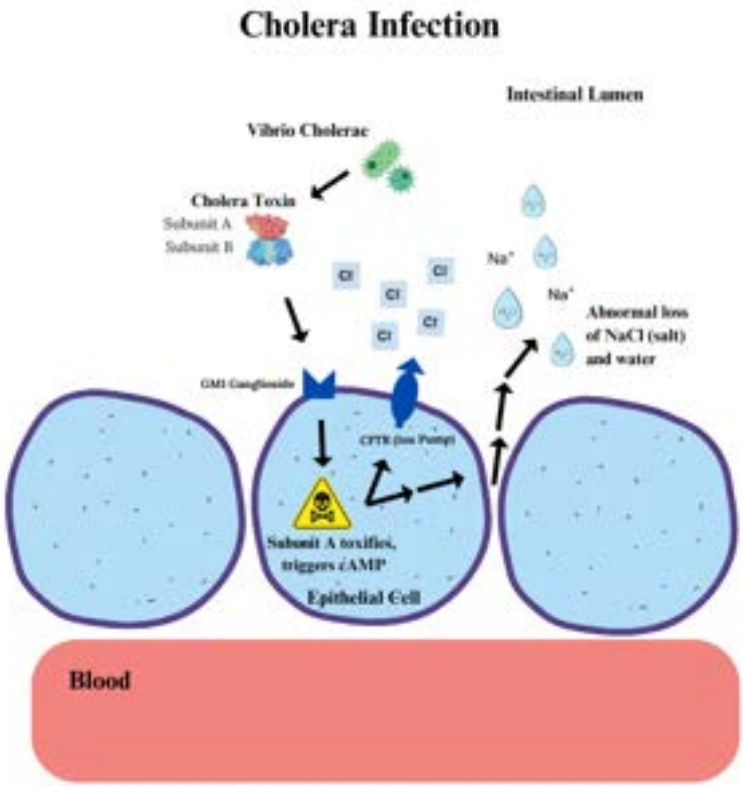

Fig 1: Cholera toxin is secreted by V. cholerae and causes the excess loss of water and NaCl through extreme diarrhea and vomiting.

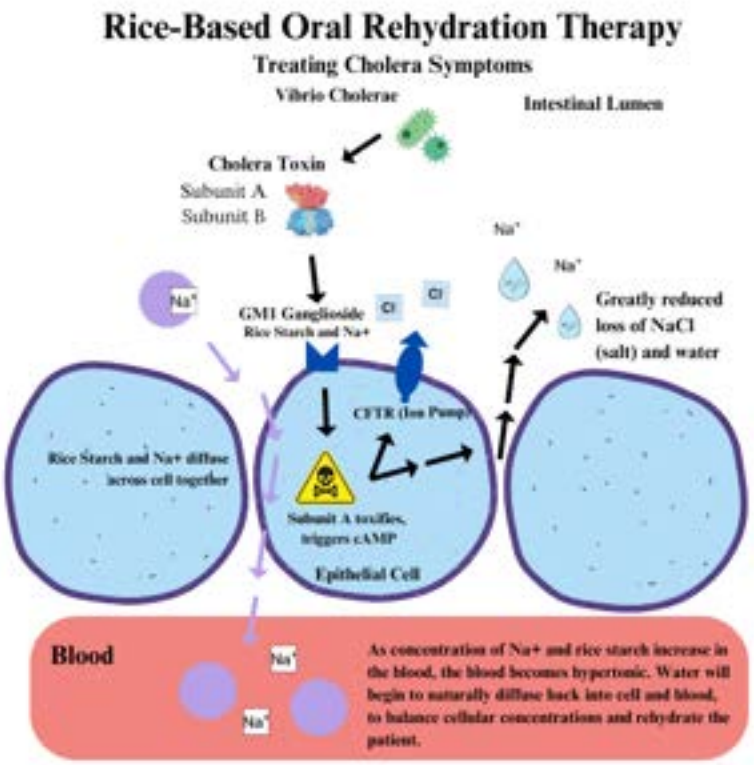

Fig 2: The improved, rice-based Oral Rehydration Therapy will treat cholera symptoms while replenishing patient cells with Na+ and water. The rice-based ORT also minimizes cholera toxin in the process, a quality glucose-based ORT does not possess.

Proposed Treatment

The proposed future technology to combat the Cholera epidemic involves the implementation of an improved oral rehydration therapy that uses a more efficacious carbon source of rice and contains bioengineered Thioredoxin enzymes which will effectively trigger isomerization by reduction on the disulfide bridge within subunit A to neutralize toxicity of the Cholera Toxin.

The enhanced ORT will contain bioengineered Thioredoxin. The scientific principles involved in the enzyme will focus on targeting the disulfide bond of cholera toxin (CT), to neutralize the toxicity. CT contains two main subunits, subunit-A which is a 240 amino acids sequence, and subunit-B which is a 103 amino acid sequence. Subunit-A is an adenosine diphosphate ribosyl transferase responsible for toxicity and cell infections and is comprised of the A1 chain linked by a disulfide bond to the A2 chain. Subunit-B is responsible for the attachment of the CT to a cell, which then allows for subunit-A to detach and infect intestinal surface cells, the GM1 ganglioside molecules, which when infected, cause intracellular cyclic adenosine monophosphate (cAMP), resulting in severe diarrhea and dehydration. Cholera toxin A-subunit is an adenosine diphosphate ribosyl transferase that conjugates the cell cytosol to

ADP-ribosylate to the regulatory G protein to activate adenylate cyclase. Adenylate cyclase is an enzyme that synthesizes cyclic adenosine monophosphate (cAMP) from adenosine triphosphate (ATP). The increased synthesis of intracellular cyclic adenosine monophosphate (cAMP) suppresses innate immune functions of monocytes, macrophages, and neutrophils (phagocytes) through the modulation of key cell functions of generation of inflammatory mediators, phagocytosis, and intracellular killing of ingested pathogens. More specifically to cholera, as cyclic AMP levels increase, the secretion and chloride ions cause misbalancing the tonicity of the intestinal epithelial cell and blood cells. As the infected epithelial cell enters the stage of rapid secretion of chloride ions due to cyclic AMP, the cell becomes hypotonic. This disturbance of the osmotic equilibrium will diffuse extreme levels H2O content down its concentration gradient, out of the cell. The rapid diffusion of water leads to fluid accumulation in the intestinal system, resulting in severe diarrhea and extreme dehydration. The enhanced ORT combined with the treatment of a specialized enzyme will prevent the triggering of cyclic AMP, preventing the hazardous functions of the Cholera toxin from infecting epithelial cells.

The technology focuses on neutralizing subunit A through eradicating the disulfide bond linking A1 chain and A2 chain of the subunit A. Should subunit B bond to the GM1 ganglioside with a non-toxic subunit A, the hosting epithelial cell will remain healthy. To delineate further, the disengagement of the A1 chain from the A2 chain, deems the toxicity of subunit A ineffective, regardless of the attachment of subunit B to an intestinal epithelial cell. Thus, prior to the bonding of subunit B to the GM1 ganglioside, the introduction of intricately modified extra cellular Thioredoxin, an enzymatic reducing agent that targets disulfide bonds, will reduce the disulfide bond that links A1 chain and A2 chain. Current technologies have shown studies in which the use of Thioredoxins have been extremely successful in reducing disulfide bonds in the cytoplasmic proteins of E.coli. The reduction process occurs as the enzymatic reducing agent, Thioredoxin, donates electrons between the sulfur atoms participating in disulfide linkage, separating the disulfide bond into individual thiol (-sulfate/hydrogen) groups. Subsequent to the eradication of the disulfide bond linking A1 and A2 chain, the Cholera toxin no longer poses a threat to the epithelial cells as Subunit A is dismantled. Future technologies will use advanced algorithms and computational models that allow Thioredoxin to very efficiently bind and target to disulfide bonds of cholera toxin, as the current technologies involving extracellular are quite limited and insufficient in efficacy.

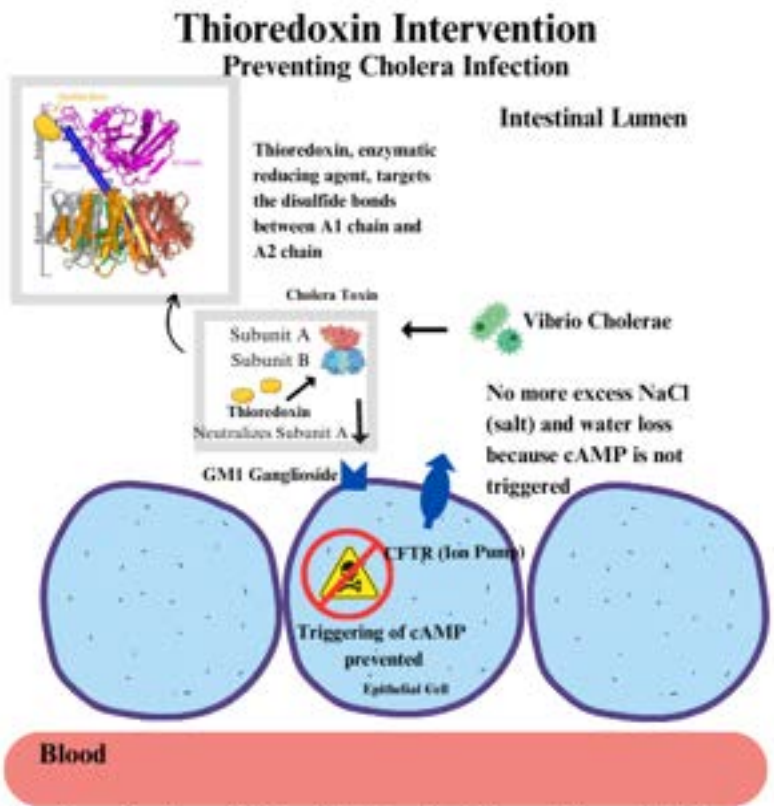

Fig 3: The primary function of Thioredoxin is to effectively neutralize subunit A by strategically breaking the disulfide bond between the A1 chain and A2 chain. This will neutralize subunit A and prevent the toxification of the epithelial cell, preventing the induction of cAMP, and therefore preventing cholera infection.

Necessary Breakthroughs

Critical advancements must occur in the methodology of transporting these enzymatic oral rehydration packets. The packaging must be able to withstand neutral everyday conditions while simultaneously maintaining an environment inside the packaging of extremely low PH between 1.5 and 3.5 so the enzyme does not denature. Furthermore, this packaging material inside needs to be safe for oral consumption. It is also critical to consider the effects of temperature on enzyme function. The optimal temperature for Thioredoxin enzymes can vary among different organisms, but it is typically around the normal physiological temperature of the organism, which is around 37 degrees Celsius (98.6 degrees Fahrenheit) for humans. Due to expected temperature fluctuations in various locations and throughout transport, a breakthrough must occur in developing a new packaging of the enzyme powder in replacement of the typical paper packaging currently used for ORT.

Another necessary breakthrough is Thioredoxin's ability to withstand the low pH's within the gastrointestinal track. Thioredoxin has been shown in studies to successfully function at a pH of 7. As the pH of the small intestines and large intestines lie between 6 to 7, Thioredoxin would comfortably remain functionable within the intestines. However, before

entering the intestinal track, the enzyme must pass through the stomach, which contains an extremely low pH of 1.5 to 2.0. This acidic environment poses a threat to Thioredoxin, as under these conditions it may very well denature and become ineffective in breaking the disulfide bonds later on in the intestines. A possible breakthrough to combat the acidic environment includes a transport capsule molecule, which would facilitate Thioredoxin's movement down the gastrointestinal tract and toward the intestinal epithelial cells to neutralize cholera toxin.

Based on recent research, an optimal material that could be developed to satisfy these conditions is PLGA. Polylactide-co-glycolide (PLGA), a biodegradable polymer that plays a pivotal role in the formulation of long-acting injectable (LAI) microspheres for protein and peptide therapeutics. The PLGA-based microsphere system involves incorporating proteins or peptides into the polymeric matrix, forming microspheres through emulsification techniques. During this process, PLGA acts as a carrier, encapsulating the therapeutic payload and providing protection against enzymatic degradation in the gastrointestinal tract. Currently, PLGA is used for protein and peptide delivery. PLGA (Polylactide-co-glycolide) emerges as a potential solution for enzymatic delivery due to its biocompatibility and versatility in forming controlled-release systems. In the formulation of oral rehydration packets, PLGA could be tailored to create protective microspheres, encapsulating enzymes and shielding them from enzymatic degradation in the harsh acidic conditions of the gastrointestinal tract. PLGA's susceptibility to acidic degradation in the stomach impedes its successful adaptation for oral use.

Critical advancements are needed to design enteric coatings or modified formulations capable of protecting encapsulated therapeutics in the stomach while enabling controlled release in the intestines. Testing the efficacy of enteric coatings or modified formulations for protecting encapsulated therapeutics in the stomach and enabling controlled release in the intestines involves in vitro experiments and techniques such as chromatography. In an in vitro study, the experiment would assess the efficacy of enteric coatings or modified formulations specifically designed for PLGA-based microspheres by subjecting them to a simulated gastric environment. This simulated gastric environment would replicate the acidic conditions of the stomach, employing an artificial gastric fluid with a pH range reflecting the physiological acidity. In order to create the gastric simulated gastric environment, several solutions will be made from water, pepsin (an enzyme found in the stomach), a buffering agent, and hydrochloric acid ranging from 3.16*10^-4M to 0.0316M. The microspheres, prepared using established emulsification techniques, encapsulate targeted therapeutic Thioredoxin enzymes. These microspheres are then exposed to the simulated gastric environment. Throughout the simulated gastric transit, collected samples undergo rigorous analyses, including high-performance liquid chromatography (HPLC), to quantitatively assess the integrity of the encapsulated enzymes. HPLC works by separating and quantifying individual components within a mixture. In this context, HPLC can specifically identify and quantify the intact enzymes within the microspheres, providing essential information regarding the preservation of Thioredoxin structural integrity following exposure to the simulated gastric conditions.

In addition, another critical development is the modification of the Thioredoxin active

site. Thioredoxin currently exists extracellularly in human cells and is commonly used for its natural anti-inflammatory effects. However, although Thioredoxin is a natural oxidoreductase protein or enzymatic reducing agent, the active site of Thioredoxin is not focused on complimenting the disulfide bond between the A1 chain and A2 chain of the subunit A of cholera toxin. The necessary breakthrough would be to modify the active site of Thioredoxin to refocus its complementary structure towards the disulfide bond of Cholera toxin. The technology to specifically modify the active site of Thioredoxin to fit cholera does not yet exist due to a limited understanding of enzyme structure-function relationships, however advancements in site-directed mutagenesis would allow enzymes in ORT to become a reality.

Design Process

Our team explored various ideas in the initial stages of our project development before arriving at our final technology. One of the alternative concepts involved developing a probiotic formula containing specific bacterial strains known for their antimicrobial properties against cholera. The rationale behind this idea was that beneficial bacteria would be introduced to the gastrointestinal tract, aiming to outcompete the harmful V. cholerae. However, there were two large fallacies in this plan. Firstly, the gut system is constantly changing. Each person's gut system is different due to diet, lifestyle, and overall health discrepancies. Probiotics may not be able to consistently outcompete and suppress V. cholerae due to the probiotics' non-specific nature. The challenges associated with probiotics' non-specific nature extend to their potential interactions with the microbial community within the gut. Introducing specific bacterial strains intended to combat V. cholerae may inadvertently disrupt the existing balance of the gut microbiota. Our proposed technology of integrating a modified enzyme resolved this issue due to an enzyme's high specificity nature, minimizing unintended consequences on the patient's gastrointestinal system. The specificity of the enzyme arises from the precise complementary shapes of the enzyme's active site and the substrate molecules due to the complex amino acid sequences. Essentially, enzymes in ORT proved to be a more effective treatment path for cholera, as it reduces the risk of unintended side effects and allows us to develop a biological component specifically tailored to the disulfide bond within Subunit A.

Upon extensive research we decided on enzyme integration in ORT as our treatment pathway. Our goal was to ensure that this enzyme neutralized the effects of the cholera toxin, a protein secreted by V. cholerae, which essentially causes the cholera symptoms of vomiting and diarrhea resulting in dehydration. Since the cholera toxin requires the attachment of its subunit A to trigger these symptoms, we first considered modifying an enzyme to have the intended function of breaking the individual peptide bonds between the amino acids of both subunit A1 and A2 of the cholera toxin, therefore rendering it ineffective. Unfortunately, cholera, like many other infectious diseases, have a high tendency to mutate and therefore differ over time periods. The structure of the cholera toxin produced by different strands varies including specifically the composition of subunit A. If we targeted subunit A with an enzyme, the enzymes effectiveness would be limited to a single variant strand, and mutating strands would not fit the complimentary

structure of the enzyme active site. It was much more effective to shift our approach to target the disulfide bond between A1 and A2 chains of the subunit A as the disulfide bond between the subunits also remains relatively unchanged as strands mutate, meaning the same enzyme can be included in each ORT package regardless of the cholera strand it needs to target.

We then had to consider how the enzyme would interact with the previously existing ORT treatment for cholera. Initially, we were planning to store the enzymes in powder form and simply add it to the ORT packages, but upon further research we realized we needed to consider the effect of salinity on enzyme function. If the enzyme were to be dissolved in the same solution of water as the electrolyte and glucose solution of ORT, the enzyme would likely denature due to the high salinity of the solution. This is why we revised the enzymes in ORT treatment to be a two-step process, in which the first package of rice based ORT would be consumed first followed by a separate packet of enzymes. The recommended interval between consuming the ORT package and the enzyme package is fifteen minutes as that is the amount of time it takes for electrolytes to be absorbed into the patient's system. Our two-step process ensures that the modified Thioredoxin does not denature before consumption, allowing it to reduce the disulfide bond within Subunit A as needed.

Potential Consequences

Bioengineered Thioredoxin disassembles the disulfide bond between A1 chain and A2 chain of subunit A, neutralizing the cholera toxin. This targeted enzymatic action holds the potential to expedite recovery and lessen the severity of cholera illness. Importantly, by preventing the disulfide bond linkage, the Thioredoxin enzymes effectively hinder the activation of intracellular cyclic adenosine monophosphate (cAMP). This disruption in the Cholera Toxin's functionality ensures that affected individuals do not experience the excessive loss of water through diarrhea, contributing significantly to the overall reduction in the severity of cholera symptoms and promoting a faster recovery.

However, there are also potential negative consequences to consider. The introduction of bioengineered Thioredoxin enzymes into the therapeutic landscape may raise concerns about safety, as the long-term effects of these enzymes on the human body need thorough examination. Additionally, the widespread implementation of this technology could face challenges in terms of accessibility and affordability, particularly in regions where resources are limited. Ensuring equitable access to enzyme-based ORT and addressing any unintended consequences is crucial to prevent disparities in healthcare outcomes. The use of bioengineered enzymes in ORT may have environmental implications if the enzymes enter water sources through human waste. In theory, the enzymes added to ORT are specific and would target only V. cholerae, but extensive testing would need to be undergone to ensure that there are minimal impacts on the surrounding cells.

The integration of bioengineered enzymes into oral rehydration therapy (ORT) for cholera offers a promising pathway for targeted and efficient treatment, contributing to faster recovery and reduced severity of cholera infections. Ultimately, the positive outcomes, such as saving lives and improving public health, make the adoption of bioengineered enzymes in ORT a

valuable and transformative approach in the fight against cholera.

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The Link Between Alzheimer's Disease and Traumatic Brain Injuries By Sarina Mehta

Abstract

Alzheimer's Disease (AD), a neurological disorder that impairs a person's cognitive abilities, is expected to impact 13.8 million Americans by 2060. Causes of AD are unknown, however, factors that can lead to AD include a combination of aging, genetic propensities, environmental and lifestyle factors. Additionally, studies have shown that adults with a history of a moderate traumatic brain injury (TBI) had a 2.3 times greater risk of developing AD and those with a history of a severe TBI had a 4.5 times greater risk. The enhanced risk is driven by the empirical evidence that changes in neural tissue due to TBIs exhibit similar aberrations to AD. Both TBIs and AD share similar pathological abnormalities such as accumulation of amyloid plaques and tau proteins, cell membrane damage, and organelle dysfunction. The purpose of this review is to 1) explore the cerebral and physiological link between TBIs and AD, 2) discuss studies that examine this link by isolating different factors that lead to the accumulation of Aβ/tau deposition leading to AD-like pathology, and 3) discuss current treatments currently used to slow the progression of Alzheimer's. While research has established an association between TBIs and an increased risk of developing AD, a conclusive link has yet to be established. The challenge is distinguishing between the neurodegenerative impact of a TBI and the natural pathological changes due to genetic factors and other risk factors of AD. Additional research is necessary to build upon evidence from past studies to determine a causal link between TBIs and AD.

Introduction

With an aging population, neurological degenerative conditions have become more prevalent. Neurological degenerative disorders affect the brain, spinal cord, and nerves throughout the body due to structural, biochemical, or electrical abnormalities in these regions (Montana DPHHS, 2020). The abnormalities can impact an individual's communication, vision, hearing, movement, and cognition. Neurological disorders currently affect 15% of the world population (Van Schependom, 2023) and are the second-highest cause of death and the leading cause of disability worldwide (Number of People, 2023). Within the wide range of neurological disorders, Alzheimer's disease and Parkinson's disease are the most common neurodegenerative diseases (Neurodegenerative Diseases). Currently, in the United States, 6.9 million people are suffering from Alzheimer's disease (2024 Alzheimer's, 2024) and this number is expected to increase to 13.8 million by 2060 (Alzheimer's Association, 2023). Alzheimer's disease, the most common form of dementia (CDC, 2022), is a brain disorder that impairs a person's memory and other cognitive abilities. The disease was named after Dr. Alois Alzheimer, who discovered abnormalities in the brain tissue of a woman who had died from a mental illness and suffered from memory loss, language problems, and erratic behavior. Her brain exhibited abnormal clumps (amyloid plaques) and tangled bundles of fibers (neurofibrillary, or tau, tangles). In addition to these plaques and tangles in the brain, the loss of connectivity between brain neurons,

nerve cells that send messages all over your body that allow you to talk, eat, walk, and think (National Institute of Neurological Disorders, 2022), also exhibited properties of Alzheimer's (National Institute on Aging, 2023). Although it is not known how amyloid plaques and tangles form within the brain, scientists believe the process begins many years before symptoms appear (Alzheimer's: Brain Changes, 2019). The causes of Alzheimer's are not fully understood but are likely related to aging, genetic propensities, and environmental and lifestyle factors (What Causes Alzheimer's, 2019). Another factor for AD that is being investigated by science researchers is a traumatic brain injury (TBI). A TBI is a head injury caused by an external force resulting in the disruption of normal brain function (2024 Alzheimer's, 2024). TBIs can occur from numerous accidents such as severe sports injuries or car accidents. Research conducted over the past 30 years, has linked moderate and severe TBI to a greater risk of cognitive decline or dementia years after the original head injury (Traumatic Brain Injury, 2016). Additionally, studies have shown that older adults with a history of moderate TBI had a 2.3 times greater risk of developing Alzheimer's than compared to older adults with no history of head injury (Traumatic Brain Injury, 2016). While TBIs are associated with an increased risk of AD, conclusive evidence that identifies TBI as a cause of dementia or AD has not been discovered. The purpose of this review is to 1) explore the cerebral and physiological link between TBIs and AD, 2) discuss studies that examine this link by isolating different factors that lead to the accumulation of Aβ/tau deposition leading to AD-like pathology, and 3) highlight current treatments currently used to slow the progression of Alzheimer's.

Physiology of Alzheimer's

The healthy human brain relies on billions of neurons to communicate in order to control all processes required for the body to function, including memory, motor skills, and breathing (What Happens, 2024). Composed of a cell body, dendrites, and an axon, neurons transmit messages from the brain to the muscles to all organs of the body (What Happens, 2024). When neurons communicate, the interaction releases a neurotransmitter, a chemical that travels across a synapse (tiny gap between neurons) and then binds to a receptor neuron that enables communication (How Do Neurons Work, 2017). Toxic changes in the brain that hinder this process lead to neurological disorders.

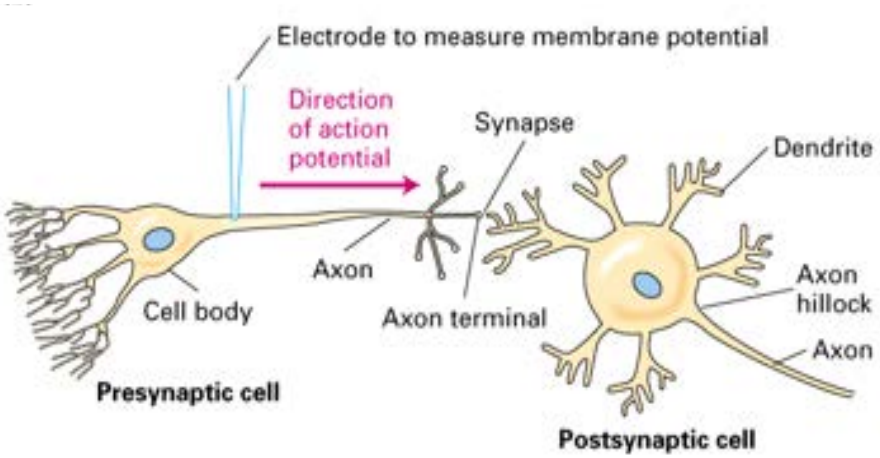

Fig 1. Depicts the communication of neurons taken from Moyes and Schulte

AD develops from the necroptosis, or cell death, of neurons due to the accumulation of neuritic plaques and neurofibrillary tangles (Kumar et al., 2024). Neuritic plaques, also called amyloid plaques, are beta-amyloid proteins (Aβ), destructive protein peptides that are 40-42 amino acids in length and accumulate between neurons (Amyloid Plaques, 2021). The Aβ is formed from the defective breakdown of a larger protein called amyloid precursor protein (APP). For Aβ to be set free and not create Aβ plaques, APP has to be cleaved by two enzymes: beta-secretase outside the membrane, and gamma-secretase (γ-secretase), resulting in C83- or C99- residue peptides, an enzyme complex within the membrane (Amyloid Plaques, 2021). The C99 peptide is the 99-aa C-terminal fragment of APP, and it is known to be a precursor of Aβ fragments that accumulate in the brain of AD patients (Takasugi et al., 2023). In healthy brains, the protein fragments or any foreign substances or debris are broken down and eliminated by microglia cells. But in an Alzheimer's brain, the microglia cells fail to eliminate the overabundance of Aβ fragments. The abnormal levels of Aβ fragments clump together to form plaques, which disrupt cell function (What Happens, 2024).

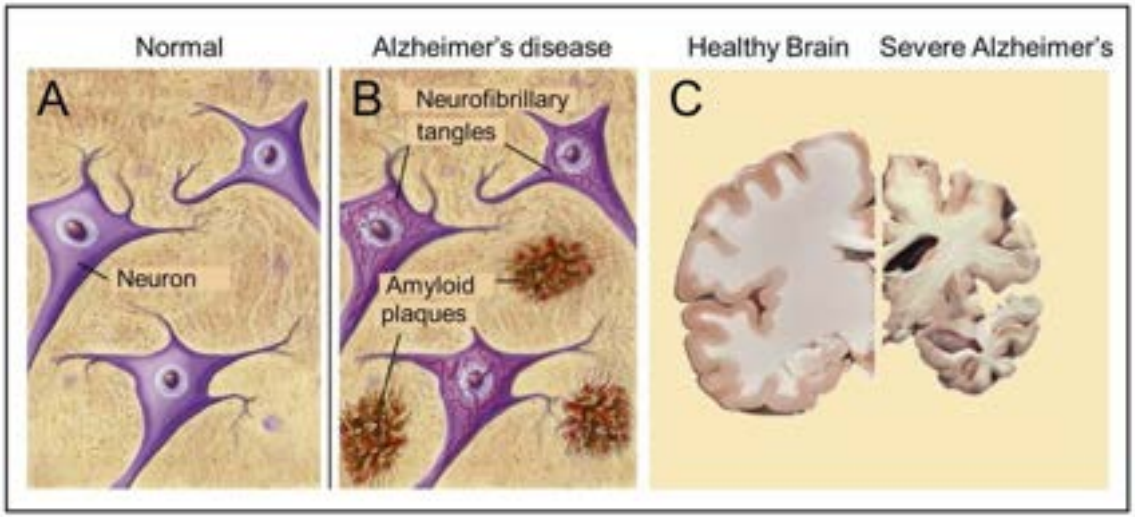

Fig 2. Compares the normal brain to a brain with Alzheimer's showing neurofibrillary tangles and beta-amyloid proteins taken from De Loof, 2019

While amyloid plaques are found in the tissue between neurons, neurofibrillary tangles are found within the neuron. These tangles are formed by the hyperphosphorylation of a protein called tau (Mahley, 2023). In healthy neurons, the tau proteins support the function of the microtubules to deliver substances like membrane vesicles and organelles throughout the neuron (Alzheimer's Disease). When the tau proteins twist into tangles and aggregate in an insoluble form, they interfere with the transport system of the microtubules, hindering communication between neurons and leading to necrosis (Alzheimer's Disease).

To combat the accumulation of Aβ, Apolipoprotein E proteins (APOE) clear the build-up of Aβ plaques via proteolytic degradation (the breakdown of proteins into smaller polypeptides), allowing APOE to slow the progression of Alzheimer's (Mahley, 2023). There are three genetic variants of APOE, known as ApoE2, ApoE3, and ApoE4. However, not all genetic variants of the APOE protein are effective in removing Aβ plaques; and the functional activities of the three ApoE variants and their impact on AD pathogenesis are not entirely known (Huang et al., 2019). Evidence suggests that ApoE4 constitutes the most important genetic risk factor for Alzheimer's disease (AD), whereas ApoE2 protects against AD (Alzheimer's Disease). ApoE4 increases the risk of developing AD due to toxic effects on cellular and metabolic mechanisms and loss of protective functions (Mahley, 2023, Raulin et al., 2022). Specifically, ApoE4 is responsible for elevating cholesterol levels in the brain (Hunsberger et al. 2019). Studies have shown cholesterol disturbances can be early signs of AD (Hunsberger et al. 2019). The three APOE variants carry different levels of amino acids involving cysteine and arginine residues at positions 112 and 158. ApoE4 has an arginine residue at both positions. It induces neuronal loss, age-related cognitive decline, and neurotoxicity when synthesized in neurons due to the arginine-112, an isoform of APOE at residue 112. Arginine-112 allows amino and carboxyl proteins to interact, altering the structure of ApoE4, resulting in fragments escaping the secretory pathway and entering the cytosol. Once ApoE4 fragments escape the secretory pathway, resulting from neuron-specific

proteolysis (the breakdown of proteins), they cause detrimental effects like enhanced tau phosphorylation, neurofibrillary tangle formation, cytoskeleton alteration, mitochondrial dysfunction, and abnormalities in the mitochondria-associated membrane (MAM) (Mahley, 2023). These effects are particularly toxic to GABAergic interneurons (neurons in the brain and nervous system that regulate the activity of cells) in the hippocampal hilus, impacting hippocampal function and impairing learning and memory (Mahley, 2023). Blocking domain interaction genetically or with structure correctors can prevent these detrimental effects, converting ApoE4 to the less damaging ApoE3-like molecule (Mahley, 2023).

Concussions and TBIs

The Center for Disease Control (CDC) defines a traumatic brain injury as a disruption in the normal function of the brain. TBIs can occur from a bump, blow, or jolt to the head, or a penetrating head injury but also from motor vehicle crashes, suicides, falls, and sports injuries (Facts, 2024). TBIs can be categorized as mild, moderate, or severe based on the type of injury, location in the brain, and age and gender of the individual (Table 1). While most moderate TBIs can cause loss of or decreased consciousness, amnesia, muscle weakness, loss of vision, change in speech, disorientation, slow thinking, or difficulty concentrating, severe cases result in extended periods of unconsciousness, coma, or death (American Association, 2019).

Table 1: Classification Based on Severity of TBIs

Mild TBI	Moderate TBI	Severe TBI
● Structural imaging: normal ● Some loss of consciousness (momentary to <30 minutes) ● Post-traumatic amnesia (momentary to <24 hours); ● Possible symptoms: headache, nausea, vomiting, fatigue, dizziness, blurred vision, irritability ● *GCS Scale: 13-15	● Structural imaging: normal to abnormal ● Loss of consciousness (> 30 minutes to less than 24 hours) ● Post-traumatic amnesia (>1 and less <7 days) ● Possible symptoms in addition to Mild: convulsions, loss or double vision, irregular breathing ● GCS Scale: 9-12	● Structural imaging: normal to abnormal ● Loss of consciousness > 24 hours ● Post-traumatic amnesia lasting more than 7 days ● Possible symptoms in addition to Mild and Moderate: inability to wake up, sudden eye or ear swelling, coma ● GSC Scale: 3-8

*Glasgow Coma Scale (GCS) is a widely used scale to assess a patient's consciousness based on eye response, verbal response, and motor response after a traumatic injury. The scale ranges from

3-15, the lower the score, the worse the condition (generally, a score of 8 or lower denotes a coma) (O'Neil et al., 2013).

Growing scientific evidence has demonstrated that a TBI can result in cellular and molecular changes in proteins due to many pathologic events, like neuroinflammation, oxidative stress, cerebrovascular impairment (edema), circulatory insufficiency, brain atrophy, and blood-brain barrier (BBB) breakdown. Each of these events can contribute to long-term cognitive and emotional disabilities in TBI patients (Wu et al., 2020)

Cerebral and Physiological Link Between TBI and Alzheimer's

Over the past couple of decades, research has linked TBIs to a greater risk of AD. The presence of amyloid plaques and tau proteins in the pathology of traumatic brain injuries suggests a link to AD. Key studies have shown that adults with a history of moderate TBI had a 2.3 times greater risk of developing AD and those with a history of severe TBI had a 4.5 times greater risk (Traumatic Brain Injury, 2016). While single TBI episodes often result in full recovery, a history of multiple TBIs raises the risk of developing AD (Traumatic Brain Injury, 2016). The definitive link between TBI and AD-like neurodegeneration is not known, but the pathogenesis of TBI and AD exhibit similar abnormalities. Early stages of both AD and TBI involve lipid metabolic alterations, cell membrane damage, and organelle dysfunction (Agrawal et al., 2022). Many studies have been conducted evaluating different causes of Aβ deposition and tau hyperphosphorylation from TBIs, which could potentially lead to AD.

A study by Agrawal and colleagues utilized a controlled cortical impact (CCI) model of TBIs in adult mice to observe an increased functionality of mitochondria-associated endoplasmic reticulum (MAM) domains after a single, moderate injury (Agrawal et al., 2022). MAM is a conduit that allows communication between the endoplasmic reticulum (ER) and mitochondria. An increase in MAM domains could trigger an increase in mitochondrial Aβ deposition. To administer the study, a controlled cortical impact injury of moderate severity was induced on adult male mice, penetrating the cortex. Molecular pathways were analyzed 1, 3, and 7 days after injury and compared to naive (or uninjured) tissue samples. The study notes that disruptions in MAM regulation are linked to elevated levels of C99 within MAM domains and the activation of cholesterol and sphingolipid turnover. These changes impact the lipid composition of brain tissues and distinct cell populations—microglial, astrocytic, and neuronal—while maintaining mitochondrial respiratory functionality.

Agrawal and colleagues found that a single episode of traumatic brain injury (CCI) leads to temporary increases in C99 and the formation and activation of MAM domains in the endoplasmic reticulum (ER). Lipidomic changes following TBIs were observed both in bulk and at cell type-specific levels, with microglia showing significant alterations consistent with MAM-specific lipid metabolic activities. The study suggests that repeated injuries could lead to sustained dysregulation of these pathways, impairing neuronal homeostasis and resulting in chronic functional impairments similar to those seen in AD. Some limitations to this study

include mechanical variation in a CCI model; the induced injury cannot replicate all effects in humans; also, injury impact characteristics may affect results. Overall, the study contends that TBI episodes have the potential to induce C99-mediated upregulation of MAM, leading to the disturbance of lipid homeostasis, possibly resulting in molecular and cellular phenotypes similar to Alzheimer's disease (Agrawal et al., 2022).

The study by Mielke and colleagues seeks to understand the link between TBI and Alzheimer's by using a population of patients with a medical record of TBI and ADRD (CDC, 2022, Mielke et al., 2022). The study identified patients with a confirmed TBI; aged 40 and over; and had at least 5 years of follow-up. For the 1,418 patients who met the criteria, 2,836 individuals (or double) were identified as age, sex, and non-head trauma referents. The study supports the hypothesis that TBI is a potential risk factor for developing ADRD, as it found that exposure to any severity of TBI at age 40 and older was associated with an increased risk of developing ADRD by 1.3 fold. However, it did not find a link between TBI and specific dementia types such as Alzheimer's disease. Potential weaknesses of the study noted by Mielke and colleagues are that it excluded those who did not seek medical attention for a TBI, and most severe cases were relatively small, limiting the power to observe an association. Mielke and colleagues contend that other studies with larger sample sizes and Alzheimer's disease-related dementia outcomes also did not find any association. Additional research is necessary to determine the relationship between traumatic brain injuries and ADRD (Mielke et al., 2022).

The review by Ramos-Cejudo and colleagues evaluates the connection between Aβ/tau deposition after TBI and the development of neurodegenerative diseases like AD (Ramos-Cejudo et al., 2018). The review postulates that cerebrovascular dysfunction (CVD) is an important contributor to neurodegeneration after TBI. Several confounding factors were evaluated. Cerebrovascular complications from a TBI can include hemorrhages, edema, changes in cerebral blood flow (CBF), BBB disruption, and inflammation. Ramos-Cejudo cites data that claims that Aβ and tau are released after a TBI, which leads to cerebrovascular injury; however, the cerebrovascular injury further induces Aβ and tau deposition creating a feed-forward loop that can ultimately lead to the development of AD-like pathology (Ramos-Cejudo et al., 2018).

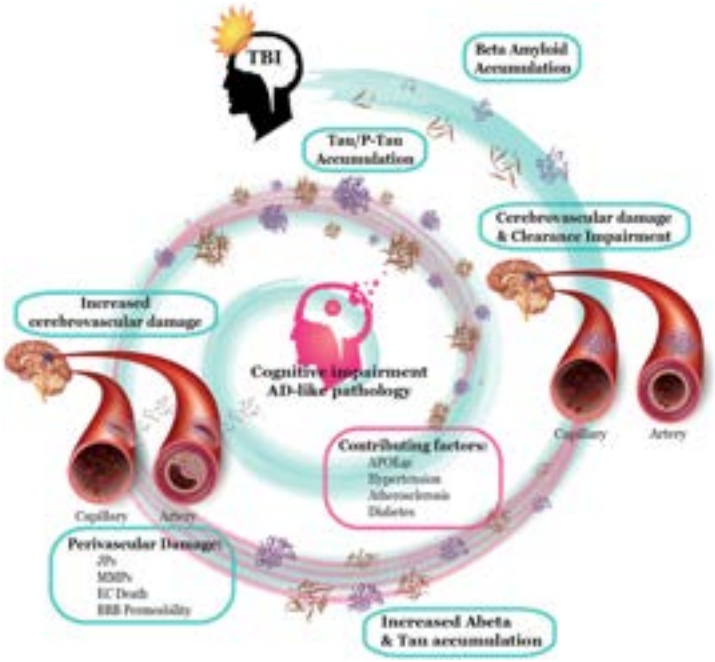

Fig 3. Depicts the feed-forward loop that can ultimately lead to the development of AD-like pathology taken from Ramos-Cejudo et al., 2018.

Also, studies have shown that a TBI can induce acute blood-brain barrier (BBB) disruption, which results in an accumulation of Aβ protein. Additionally, hypoperfusion, vascular dysfunction, and ischemia after TBI may all contribute to Aβ deposition. Concerning tau, animal studies have shown injury causes tau to become phosphorylated, misfolded, aggregated, and cleaved, generating neurotoxic tau peptide fragments (Wu et al., 2020). Recent data also suggests that tau accumulation contributes to cerebrovascular dysfunction (Ramos-Cejudo et al., 2018).

More studies need to be conducted to further elucidate the connection between TBI and CVD and the consequent acceleration of Aβ/tau deposition leading to AD-like pathology.

Treatments

Currently, doctors use several methods to diagnose AD including a review of medical history, assessment of symptoms, brain imaging (to evaluate brain degeneration), and lab tests (i.e. a cerebrospinal fluid examination to determine the presence of Aβ and tau proteins) (Breijyeh and Karaman, 2020) The latest breakthrough for diagnosing AD is the development of a blood test to identify Aβ and tau proteins, which can lead to early detection and treatment (Medical Tests, 2019). Current blood tests to diagnose AD do not have FDA approval but are demonstrating similar accuracy to spinal taps and brain scans (Schneider, 2024). Moreover, these blood tests can detect molecular signs of AD even before symptoms emerge (Schneider, 2024). While there are currently no specific treatments approved specifically for TBI-induced AD, individuals who have experienced TBI and are at risk for or have developed AD can seek out treatment plans aimed at managing symptoms. FDA-approved medications have modest benefits for the treatment of mild to moderate AD and do not prevent the progression of the disease.

Currently, the first line of defense for AD patients includes acetylcholinesterase inhibitors (rivastigmine, galantamine, donepezil) and an N-methyl-D-aspartate (NMDA) receptor antagonist (memantine) (Sankar, 2024). While these treatments curb symptoms, they are not able to prevent the progression (Sankar, 2024). Another treatment for AD that is gaining attention is immunotherapy (or utilizing the patient's immune system to target abnormalities), more specifically, active and passive immunization (Valiukas et al., 2022). Active immunization is a vaccination where a fragment of Aβ is administered to stimulate an antibody response (Valiukas et al., 2022). However, active vaccine therapy for the removal of both Aβ deposits and tau has not gained FDA approval (Valiukas et al., 2022). On the other hand, passive immunization uses monoclonal antibodies (mAbs), or synthetic peptides, to reduce the amount of Aβ in the brain by triggering the immune system to break down the Aβ proteins (Valiukas et al., 2022). In 2023, the FDA approved Leqembi (Lecanemab), the first amyloid beta-directed antibody that reduces Aβ plaques that form in the brain (Three Promising Drugs). Lecanemab is given as an IV infusion every two weeks and has been shown to slow the progression of AD by 27% (Three Promising Drugs).

While vaccines for AD are feasible, their efficacy is unpredictable, given that patients will have varying immune responses. However, vaccines are less costly than passive therapies and likely to have longer-term effects, making them a possible treatment option once they receive FDA approval (Valiukas et al., 2022). Other efforts to develop disease-modifying drugs include research that studies connections between heart disease, stroke, diabetes, and high cholesterol to develop medicines for AD (Mayo Clinic, 2021). Targeting Aβ and tau pathology, the hallmark of AD pathology, will continue to dominate therapeutic research. In addition, given the degenerative nature of AD, early intervention in disease progression will also be critical for disease-modifying and disease-preventing treatment (Valiukas et al., 2022).

Conclusion

As the number of people living with AD is expected to rise to 13.8 million people by 2060 (up from 6.9 million people currently), AD research to develop effective interventions should remain at the forefront of scientific research[5]. While many factors may lead to AD, such as aging, genetic propensities, and environmental and lifestyle factors, this review focuses on the link between TBI and AD (What Causes Alzheimer's, 2019). Studies indicate that individuals with a history of moderate or severe TBIs face a substantially higher risk of developing AD (Traumatic Brain Injury, 2016). Research over the past couple of decades has established an association between TBIs and an increased risk of developing AD, however, a conclusive link has yet to be established. The challenge is distinguishing between the neurodegenerative impact of a TBI and the natural pathological changes due to genetic factors and other risk factors of AD (LoBue et al., 2018). In this review, we attribute the potential link between the two conditions to the increased presence of amyloid plaques and tau proteins, cardinal features in the pathology of both TBIs and AD. To research this link, this review evaluated three case studies that analyzed

different contributing variables that can trigger the development of Aβ deposits and the formation of tau tangles from a TBI leading to the pathology of AD.

The study by Agrawal and colleagues utilized a controlled cortical impact (CCI) model of traumatic brain injury in adult mice to observe an increased functionality of MAM domains after a single, moderate injury (Agrawal et al., 2022). An increase in MAM domains could trigger an increase in mitochondrial Aβ deposition. The study data supports the hypothesis that the upregulation of MAM is crucial in lipid metabolic disturbances during the acute phase post-brain injury, opening new perspectives on TBI as a potential environmental factor contributing to AD (American Association, 2019).

The study by Mielke and colleagues analyzed the link between TBI and Alzheimer's by using a population of patients in Olmsted County, MN with a medical record of both a TBI and ADRD (CDC, 2022, Mielke et al., 2022). The study identified patients with a confirmed TBI; aged 40 and over; and had at least 5 years of follow-up. The study supports the hypothesis that exposure to any severity of traumatic brain injury at age 40 and older was associated with an increased risk of developing Alzheimer's disease-related dementia by 1.3-fold (Mielke et al., 2022). However, it did not find a link between traumatic brain injuries and specific dementia types including Alzheimer's disease.

The study by Ramos-Cejudo and colleagues explored various animal and human studies with a focus on cerebrovascular dysfunction as a contributing factor to understanding the consequences of TBI on the development of AD-like pathology (Ramos-Cejudo et al., 2018). The study referenced other studies that found TBIs induce acute disruption of the blood-brain barrier (BBB), leading to increased Aβ protein levels. Additionally, injury triggers the phosphorylation, misfolding, aggregation, and cleavage of tau protein. Experimental data suggests that the release of Aβ and tau following a TBI can cause cerebrovascular injury, further exacerbating Aβ and tau deposition, resembling a feed-forward loop similar to Alzheimer's disease (AD) pathology. The review underscores that there is an association between TBI-induced neurovascular impairment and AD-like pathology, however further research is necessary to understand and identify a definitive pathway (Ramos-Cejudo et al., 2018).

Current therapeutic approaches mainly focus on managing symptoms and can not change the underlying disease pathology. Acetylcholinesterase inhibitors, NMDA receptor antagonists, and immunotherapy are among the strategies being explored. In 2023, the FDA approved Leqembi (Lecanemab), the first amyloid beta-directed antibody that reduces Aβ plaques that form in the brain. Early detection methods, including blood tests for Aβ and tau proteins, offer potential avenues for intervention. The ongoing efforts in understanding the complex relationship between TBIs and AD, coupled with advancements in treatment strategies, underscore the importance of continued research to unravel the intricacies of this association and develop effective interventions for those at risk or affected by TBI-induced AD.

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Global Ascorbic Acid Concentrations and Deficiencies By Katelyn Smith

Introduction

Tracing back to 1550 BCE, scurvy was found to be caused by a diet deficient in vitamin C by 19th-century scientists. The purpose of this study was to identify the concentration of ascorbic acid in fruits from a wide range of countries worldwide to infer the risk of ascorbic acid deficiencies in cultures based on the fruit's native country. The fruits in this study were not limited to a specific region, but were native to diverse regions globally. For instance, the Actinidia chinensis (SunGold Kiwi) was native to China; the Artocarpus heterophyllus (Jackfruit) was native to India; the Hylocereus undatus (Dragon Fruit) was native to Central and South America; the Citrus sinensis (Orange) was native to the Malay Archipelago; and the Cucumis metuliferus (Horned Kiwano Melon) was native to Nigeria. Before being titrated in an iodine solution, the fruits were juiced and frozen for two weeks. The process of freezing was due to limited lab access. After titrating, the *Artocarpus heterophyllus* was discovered to contain the highest concentration of ascorbic acid at 79%, and containing the lowest percentage concentration of ascorbic acid at 8.40% was the *Cucumis metuliferus*. The concentrations indicate cultures native to India have the lowest risk of ascorbic acid deficiencies and cultures in Nigeria have the highest risk of ascorbic acid deficiencies. The results of this study are not just informative, but also have the potential to significantly impact public health, by alluding to regions with vitamin C deficiencies, including increased scurvy incidents. Medical professions can quickly aid human life through the knowledge of specific vitamin deficiencies worldwide.

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Purpose

This study aims to ascertain the concentration of ascorbic acid in fruits from various countries worldwide to deduce the risk of vitamin C deficiencies in cultures derived from the fruit's origin.

Hypothesis

If the concentration of ascorbic acid is determined for *Citrus sinensis*, *Cucumis metuliferus*, *Artocarpus heterophyllus*, *Actinidia chinensis*, and *Hylocereus Undatus,* then the *Citrus sinensis* will contain the highest percentage of ascorbic acid per milliliter.

Background Information

The *Actinidia chinensis* (*A. chinensis*), commonly known as "SunGold kiwi," originates within the mountain ranges of southwestern China (Henare; Page; Janick, "Horticultural Reviews, Volume 6"). Currently, the SunGold kiwi is cultivated globally (Li and Zhu). Farmed and harvested internationally, the *A. chinensis* is known as the "king of fruits" due to its extraordinarily high vitamin C concentration, balanced nutritional composition of minerals, and dietary fiber (Huang et al.). As the "king of fruits," the *A. chinensis* is utilized as a folk medicine due to its high source of nutrients (M. He et al.). In folk medicine, the root and bark of *A. chinensis* include medicinal effects such as wind and heat dispelling, blood circulation improvement, and detumescence properties (He et al.). It can also treat rheumatoid arthritis, bruises, swelling, filariasis, hepatitis, and dysentery (He et al.). Due to A. chinensis being a high source of nutrition, it makes up a significant share of the recommended daily value of vitamin E, vitamin C, dietary fiber, and microelements (He et al.). Microelements are enzymes that contribute to plant metabolism to reduce oxidation-reduction (Nieder et al.) In addition to containing numerous vitamins and microelements, the *A. chinensis* also contains bioactivities, which are used to obtain general nutritional needs in humans (He et al.; Weaver). Containing other beneficial properties, *A. chinensis* consists of antitumor, antioxidant, anti-inflammatory, antimicrobial, immunoregulatory, hypolipidemic, antidiabetic, cardiovascular protective, and hypnotic properties (He et al.). The *A. chinensis* is beneficial to include in daily diets because its promising nutrients contain beneficial properties to maintain general health and welfare.

With similarly high nutritional benefits to the *A. chinensis*, the *Artocarpus heterophyllus* (*A. heterophyllus*)is native to the western Ghats of Malaysia and India. The *A. heterophyllus*, commonly known as the jackfruit, is a species of tree from the mulberry family (Azizur Rahman et al.). Coming from the mulberry family, the meat within the *A. heterophyllus* is around three to five mm thick ("The Wealth of India: A Dictionary of Indian Raw Materials and Industrial Products (Industrial Products—Part I)"). The large fruit is known as "poor man's food" as it is rich in nutrients and inexpensive (Enos Tangke Arung et al.). The *A. heterophyllus* has several uses besides its economic and nutritional viability, making it necessary in daily food consumption. Containing 287-3323 mg of potassium, 30.0-73.2 mg of calcium, and 11-19 g of carbohydrates, the flakes of the ripe fruit of the *A. heterophyllus* have a high nutritional value (Ranasinghe et al.). Every part of the *A. heterophyllus* is utilized, such as the waste and leaves of the fruit being provided as feed for goats, cattle, and pigs (Enos Tangke Arung et al.).

The *A. heterophyllus* can be utilized similarly to the *Hylocereus undatus*. With the ability to grow for 20 years and cultivate 800 fruits in just 100 acres, the *Hylocereus undatus* (*H. undatus*), commonly known as the "dragon fruit," originates from Mexico and Central and South America (Britton and Rose; Janick, "Horticultural Reviews, Volume 18"; Julia Frances Morton; Rojas-Sandoval and Praciak; Merten). The produce has expanded from South America and is currently cultivated worldwide (Merten). While being cultivated globally, *H. undatus* has beneficial and nutritional properties in several stages of its growth (Schiffermuller). The young stems and flowers of *H. undatus* are eaten as vegetables or used for homemade medicine when

dried (Schiffermuller). Consuming ripe *H. undatus* fruit frequently helps with coughs, asthma, and healing wounds due to its high vitamin C concentration (Schiffermuller). The *H. undatus* contains 5.64mg of vitamin C (Shah et al.). Most importantly, due to the high concentration of Vitamin C within the fruit of *H. undatus*, the fruit plays a crucial role in enhancing the immune system and stimulating other antioxidants (Schiffermuller).

Containing a high concentration of vitamin C as well, the *Citrus sinensis* (*C. sinensis*), initially cultivated in China and the tropical expanse of the Malay Archipelago is widely known as the "orange" (Petruzzello). Notably, the native tropical fruits of China and the Malay Archipelago do not ripen or improve in quality after being picked (Petruzzello). The *C. sinensis* originated not only from eastern territories but from a purposeful cross between the *Citrus reticulata* (hybrid mandarin orange) and the *Citrus maxima* (hybrid pomelo) in southern China ("Citrus Sinensis "Washington" - Plant Finder"). The delightful cross between the two created a fruit rich in nutrients and an array of other beneficial properties ("Orange (Fruit) - New World Encyclopedia"). The pericarp, the white part of the *C. sinensis*, and the pith have the same amount of vitamin C as the flesh ("Orange (Fruit) - New World Encyclopedia"). *C. sinensis* blossoms have been used as fragrances and flavoring for cleaning agents, perfumes, and wood conditioners— ("Orange (Fruit) - New World Encyclopedia"). However, the most significant purpose of *C. sinensis* lies in its high concentration of different types of vitamin C ("Orange (Fruit) - New World Encyclopedia"). The C. *sinensis* is best known for being the leading treatment and cure for scurvy (Mayo Clinic). Though *C. sinensis* is known for being remarkably high in vitamin C concentrations, the concentrations of this nutritious fruit can be affected by climate conditions, maturity state and position on the tree, the species and variety of fruit in question, the container holding the fruit, and handling and storage (Nagy).

Not far from the origins of the C. *sinensis* in China, the *Cucumis metuliferus* (*C. metuliferus*) is native to Nigeria and commonly named the "horned kiwano melon" (Carr and Maggini). Expanding from Nigeria, the *C. metuliferus* is currently cultivated in Australia, Kenya, Israel, California, Chile, and New Zealand (Carr and Maggini; Dembitsky et al.). The factor allowing this fruit to be grown internationally is its adaptability to successfully grow outside the geographical area of its native home of Africa, thus making it possible for many parts of the world to enjoy this fruit (Wannang et al.). Due to its adaptability, the *C. metuliferus* is characterized by its rapid growth and intolerance to low temperatures (Vieira et al.). The *C. metuliferus* adaptability allows the plant to grow in semi-evergreen forests, woodland, wooded grassland, grassland, and abandoned cultivated areas (Vieira et al.). Though *C. metuliferus* has productive benefits due to its adaptability to grow over various regions, the fruit contains rich amounts of nutrients beneficial to consumers. The pulp of *C. metuliferus* is highly concentrated with vitamins B and C while accumulating lower concentrations of vitamin A (Clint et al.). Nonetheless, the principal vitamin in the peel is vitamin C (Ezekaibeya et al.). Including more nutrients, the seeds contain higher concentrations of Fat-soluble vitamins such as D, E, K, and A and complex B vitamins like thiamin, folic acid, and riboflavin than vitamin C (Wannang et al.). As antioxidants within the nutrients of the *C. metuliferus*, vitamins C and E prevent the cells

from oxidative stress-induced cellular damage by searching for reactive oxygen species (Traber and Stevens). The *C. metuliferus* contains beneficial vitamins and properties that allow the fruit to be grown and cultivated in vast regions of Africa.

Scurvy

The first cases of scurvy were reported in ancient Egypt in 1550 BCE. (Magiorkinis et al). Continuing to be discovered throughout history, scurvy was prevalent among sailors (Magiorkinis et al.). Around 1500 AD, a sailor, Vasco da Gama, who finished his tour around Africa, observed his shipmates succumbing to symptoms such as swelling legs, gums, and arms (Magiorkinis et al.). Gama noted that eating oranges, which were high in vitamin C, reduced their symptoms of scurvy(Magiorkinis et al.). Centuries later, the disease was researched by a 19th-century English biochemist named Sir Frederick Gowland Hopkins (Magiorkinis et al.). Hopkins discovered adding fresh cow's milk to a stunted rates diet could allow the rat to retain its regular growth rate because of the vitamin C concentration in the milk (Magiorkinis et al.). Today, scurvy tends to be identified as an unusual illness, transpiring only in children with meager diets, neglected elderly citizens, and citizens enduring intense diets (Magiorkinis et al.). Patients suffering from scurvy are regularly treated with vitamin C, otherwise known as ascorbic acid (Mayo Clinic). Scurvy patients experience bleeding gums, anemia, lethargic wound healing, and bruising before being treated with ascorbic acid(Mayo Clinic). Vital for the body's healing process, the nutrient ascorbic acid is necessary to form collagen, muscle, cartilage, and blood vessels (Mayo Clinic). Ascorbic acid helps the body store and assimilate iron (Mayo Clinic). Ascorbic acid is an antioxidant that defends the body's cells from free radicals developed from breaking down food or exposure to X-rays, sun rays, and tobacco smoke (Mayo Clinic). These free radicals have been discovered to contribute to cancer and heart disease (Mayo Clinic). With a pallet containing a wide range of vegetables and fruits, ascorbic acid can reduce the risk of colon, breast, and lung cancer (Mayo Clinic). However, it is unspecified whether or not the defensive result from consuming the produce and vegetation is a consequence of the concentration of ascorbic acid in the food (Mayo Clinic). Some studies have suggested that oral ascorbic acid supplements accompanied by other vitamins will prevent age-associated macular degeneration, which is when the retina in the eye is damaged (Kierstan Boyd; Mayo Clinic). Selected analyses discovered that those with a higher concentration of ascorbic acid in their diets tended to have a reduced risk of cataract formation (Mayo Clinic).

Studying ascorbic acid during this experiment has proved problematic when obtaining research on the number and where scurvy cases occur due to limited monitoring systems in less developed countries worldwide ("Vitamin c Fortification of Food Aid Commodities: Final Report"). Nonetheless, previous research has been concluded in other experiments to determine the concentration of ascorbic acid in various fruits used in this paper's research compared to other fruits not used in this study. *C. sinensis* was 47.84 milligrams per gram of vitamin C (Najwa and Azrina). The *A.heterophyllus* had seven to ten milligrams per 100 grams of vitamin C (Ranasinghe et al.). The *C. metuliferus* had 5.3 mg per 100 grams of vitamin C ("FoodData

Central"). The *H. Undatus* had 4.3 milligrams per 100 grams ("FoodData Central"). The *A. chinensis* 161.3 milligram of vitamin C per 100 grams (Richardson et al.).

Though the concentration of vitamin C in the fruits previously listed may sound high, the body does not naturally generate ascorbic acid (Mayo Clinic). The recommended daily amount of ascorbic acid is 90 milligrams for men and 75 milligrams for women (Mayo Clinic). Consuming a broad spectrum of foods high in ascorbic acids, such as potatoes, cabbage, tomatoes, berries, peppers, brussel sprouts, spinach, and broccoli, will help meet nutritional standards (Mayo Clinic). Nevertheless, consuming ascorbic acid supplements only for their antioxidant properties will not have the same effect as food's naturally occurring ascorbic acid nutrients (Mayo Clinic).

Ascorbic Acid Degradation

The ascorbic acid molecule consists of more than 20 various proteins and 42 explicit peptides (Magiorkinis et al.). Ascorbic acid substantially facilitates an organism's growth and development by synthesizing proteoglycan and glypicans, which are affiliated with the cell membrane (Magiorkinis et al.).

Though one of the most frequently used supplements, vitamin C is precarious ("Do Vitamin Pills "Go Off"?"). Vitamin C is known for swiftly degrading in exposure to air, heat, and light ("Do Vitamin Pills "Go Off"?"). When vitamin C is stored, deliquescence, when a substance melts to become a liquid, occurs due to the moisture from the atmosphere being engulfed by the vitamin C ("Do Vitamin Pills "Go Off"?"). Two forms of vitamin C were tested in an experiment, sodium ascorbate and ascorbic acid, consisting of different deliquescence points ("Do Vitamin Pills "Go Off"?"). Although both are counted as unstable substances, results indicated ascorbic acid was more stable than sodium ascorbate ("Do Vitamin Pills "Go Off"?"). Ascorbic acid appeared more stable than sodium ascorbate at 25 C in all humidity conditions for up to eight weeks ("Do Vitamin Pills "Go Off"?"). Variables such as humidity and temperature have an optimal influence on vitamin C degradation ("Do Vitamin Pills "Go Off"?"). The substance does not become noxious; the nutrients remaining in vitamin C only become questionably viable ("Do Vitamin Pills "Go Off"?"). For vitamin C to stay as optimal as it can be, it is recommended to be preserved in a dry and cool area ("Do Vitamin Pills "Go Off"?").

Materials and Methods

The fruits juiced in this experiment were chosen based on their origins and store availability. Derived from their origin, the produce was selected from a broad spectrum of distant global regions. The fruits studied in this experiment were chosen from a small variety of locally sold produce from international suppliers. This may cause minimal change between natively grown fruits and internationally supplied fruits.

A total of 25 titrations were completed for each of the five fruits, including the *A. chinensis*, *A. heterophyllous*, *H. Undatus*, *C. sinensis*, and *C. metuliferus*. The *H. undatus*, *C. metuliferus*, *C. sinensis*, and *A. heterophyllous* were bought on December 11th. The *A. chinensis*

was bought on December 23rd. The *C. metuliferus* was juiced and refrigerated on December 12th, then titrated on December 14th. The *H. undatus* was juiced on December 18th and frozen until titrated on December 18th. The *A. heterophyllous* was juiced on December 21st and frozen until titrated on December 12th. The A. *chinensis* and the *C. sinensis* were juiced and frozen on December 23rd until titrated on December 28th. Roughly, the period between being bought and juiced to being titrated was one to two weeks. The overall percentage of ascorbic acid degradation between each fruit co-occurred; therefore, the difference between ascorbic acid concentrations is still valid.

Helmenstine, 2019 created the lab producer used. The iodine solution was made with NaI, $NaIO_3$, 3M H_2SO_4, and distilled water. The solution was kept in a 600ml beaker with a sheet of aluminum foil to reduce evaporation. The vitamin C standard solution was made with vitamin C (ascorbic acid) tablets and distilled water. The vitamin C standard solution was contained in a 250-volumetric flask. 12 ml of the standard solution was used to identify the amount of iodine solution needed to reach equilibrium. The starch solution was produced with soluble starch, distilled water, and a hot plate to help dissolve the solution. The 1% starch solution was kept in a 200 ml beaker with a sheet of aluminum foil over the top to reduce the effect of evaporation. 12 ml of each fruit juice was added one at a time, for 25 titrations each, into a 125 ml Erlenmeyer flask and titrated with a burette. The mixture was mixed with a magnet.

Results

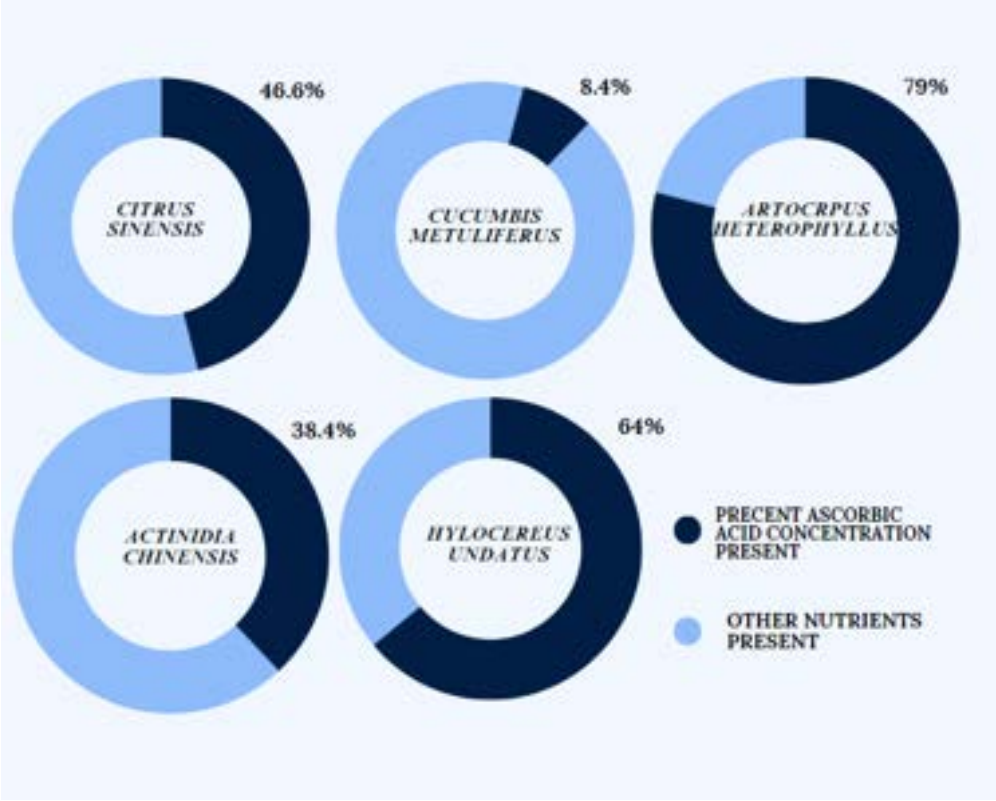

Figure 1. Vitamin C concentration per fruit. Various fruits, including C. Sinensis, C. metuliferus, A. heterophyllus, A. chinensis, and H. undatus, were titrated for ascorbic acid concentrations to determine their viability to cause ascorbic acid deficiency in the native population.

	Average Iodine Solution Titrated (ml)	Ascorbic Acid Concentration (%)	R^2 Values	R^2 Average
Ascorbic acid	5.00	100.	-	-
C. sinensis	2.33	46.6	.6974	.7394
C. metuliferus	0.420	8.40	.7476	
A.heterophyllus	3.95	79.0	.7572	
A.chinensis	1.92	38.4	.7783	
H. undatus	3.20	64.0	.7177	

Table 1. Various produce have been tested, including fruits native to places worldwide such as China, Africa, Mexico, India, and the Malay Archipelago. The fruits were juiced and then frozen for two weeks before titrating with an iodine solution. To determine the percentage of ascorbic acid present in the fruits, the average milliliters of fruit juice from 25 trials were each divided by the average ascorbic acid the iodine solution took to reach the endpoint. Then, after the percentages were derived from the averages, the standard deviation was performed using the same averages to determine the accuracy of each titration.

C. metuliferus had a vitamin C concentration of 8.40%, *C. sinensis* had a vitamin C concentration of 46.6%, *A. chinensis* had a 38.4% concentration of vitamin C, *A. heterophyllus* had a 79.0% concentration of vitamin C, and *H. undatus* had a concentration of 64.0% vitamin C (Figure 1). Though the hypothesized fruit with the highest concentration was *C. sinensis*, the trial outcome suggests that *A. heterophyllus* has the highest concentration of vitamin C at 79.0% while *C. sinensis* only had a vitamin C concentration of 46.6%. The lowest vitamin C concentration resulted from *C. metuliferus* at concentrations of 8.40%.

C. sinensis, *C. metuliferus*, *A. heterophyllus*, *A. chinensis*, and *H. Undatus* were tested to find the average amount of iodine solution used to calculate the percentage of vitamin C concentrated in the fruits (Table 1). The *C. sinensis* used 2.33ml of iodine solution to reach the endpoint. Using 2.33ml of iodine solution resulted in a vitamin C concentration of 46.6%. 0.420ml of iodine solution reached the endpoint for the *C. metuliferus*. The calculated concentration of vitamin C for *C. metuliferus* was 8.40%. The *A. heterophyllus* reached the endpoint using 3.95ml of iodine solution. 79% of vitamin C was calculated for the *A. heterophyllus*. The *A. chinensis* used 1.92ml of iodine solution, which resulted in a vitamin C concentration of 38.4%. Finally, 3.20ml of iodine solution was used to reach the endpoint for *H. Undatus*. The resulting vitamin C concentration was 64%.

The titration for *C. sinensis* had a calculated R^2 value of .6974. Estimating the R^2 value yielded .7476 for the titration of the *C. metuliferus*. The R^2 value for the *A. heterophyllus* titration

resulted in .7562. The *A. chinensis* titration determined an R^2 value of .7783. A .7177 R^2 value was calculated for the titration of *H. undatus*. The average R^2 value for the 125 titrations performed in this experiment is .7394. Roughly, the experiment had a 73.94% accuracy rate.

The fruit tested contained striking smells, such as the A.heterophyllus, which smelled like an overripe pineapple and had a yellow color to its juice. The *A.chinensis* looked pale yellow, and there was a scent of granny smith apples. The *C. metuliferus* was light green with an almost jelly-like consistency and smelled like a cross between a melon and an orange. The *H. undatus* did not have a distinct scent but had a pure white color in its juice. The *C. metuliferus* smelled like orange juice and looked orange.

Discussion

The results show that the fruit with the optimal ascorbic acid concentration was the A. heterophyllus (79%), and the fruit with the undermost concentration of ascorbic acid was the C. metuliferus (8.4%). These results do not support the hypothesis. In turn, the A. heterophyllus resulted in the optimum ascorbic acid concentration of 79%, while the *Citrus sinensis* had 46.6% ascorbic acid concentration.

The *A. heterophyllus* is native to India; thus, based on the results from this experiment, Indian cultures are likely not to experience ascorbic acid deficiencies. Native to Mexico and South America, the *H. undatus* had the second-highest concentration of ascorbic acid, indicating that Mexican cultures likely do not suffer from ascorbic acid deficiencies either. Thirdly, the *C. sinensis*, native to China and the Malay Archipelago, suggests that Chinese cultures do not have a high risk of ascorbic acid deficiencies. A.chinensis, native to China, is likely to have a higher risk of ascorbic acid deficiencies. Lastly, native to Africa, the *C. metuliferus* had scarce amounts of vitamin C, indicating that cultures, specifically Nigeria and Africa, may have a high likely chance of ascorbic acid deficiency.

This research holds significance because it can be utilized to warn the risk of ascorbic acid deficiencies in specific regions. If the fruits native to a particular region are consumed by the cultures living in the area, then it can be inferred that those citizens consume part of their daily nutrients from those fruits. Countries with native fruits lacking nutrients like ascorbic acid can prepare and educate their civilizations on avoiding the disease. They can also disseminate popular treatments of scurvy to treat the disease faster. Better medical care can be provided to countries suffering from increasing malnutrition rates if such studies can predict the root causes of malnutrition.

Conclusion

This research studied an arrangement of exotic fruits such as the *A. chinensis*, *A. heterophyllus*, *H. Undatus*, *C. sinensis*, and *C. metuliferus* to discover which produce contained the highest concentration of acorbic acid. My hypothesis was not supported as the *A. heterophyllus* had the greatest concentration of ascorbic acid. It is necessary to determine the risk of ascorbic acid deficiencies in cultures based on fruits native to their origins. The research

results indicated that *C. metuliferus* had the lowest concentration of ascorbic acid. This signifies that cultures native to India have lower risks of developing ascorbic acid deficiencies because of the *A. heterophyllus* originating in India. In contrast, cultures originating from Nigeria have a high risk of developing ascorbic acid deficiencies because Nigeria is the native region of the *C. metuliferus*.

This research can be further continued by testing other vitamins in these fruits, such as vitamins A, D, or E. More research would be required to ascertain the ascorbic acid deficiencies on a global scale, as there are no studies with comprehensive data. This research can be used to identify regions where people are suffering from malnutrition. Healthcare workers must know where there is a higher chance of ascorbic acid deficiency worldwide. Once they are made aware, they can quickly extinguish scurvy.

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The Visual Element of Marketing: Exploring the Marketing Potential of Visual Elements in Logo Designs and Social Media Advertisements By Lucy Liu

Abstract

Throughout the fashion and cosmetic industries, few brands are commonly used and recognized. This paper explores how visual elements can help these two industries market their products and be more recognized. It specifically focuses on how visual elements are used in logo designs and social media posts as there is a gap in previous research regarding how visual elements are implemented in social media posts to attract more consumers. This paper argues that by paying more attention to how logos and social media posts are designed, brands can increase their chances of being more successful in industries that are highly competitive. The study was conducted with a literature review, content analysis of current logo designs and social media advertisement posts, as well as a survey to collect new data. The insight of this study contributes to the marketing strategies brands can use to expand their business in the fashion or cosmetic industry.

Keywords: visual elements, logo designs, marketing, social media marketing, fashion industry, cosmetics industry

Introduction

Beauty advertisers in the U.S. spent around 373 million dollars for product promotion in January of 2023 (Faria, 2023). But how effective were their methods? Over the years, the fashion and cosmetic industry have grown more and more competitive. These industries are always coming up with new trends due to the rise of social media usage (Moyer, 2022). As a result, companies have found new ways to advertise their products matching the growth of increased social media activity, one of which is the use of Instagram posts (Ricchiardi, 2020). Through these social media posts, companies have to advertise their products in an appealing but also in a way that summarizes the information and quickly grabs a person's attention. This is why visual elements can be so important.

Social media advertisements are not the only tools that are used to quickly grab a possible customer's attention. Logo designs can also play a role in setting one brand apart from the others. While there are so many fashion and cosmetic products, only a few brands are well known and commonly used. In fact, on average, it will take 5 to 7 times of seeing a logo before a customer remembers the brand, unless that brand is very well known, like Gucci (Ariella, 2022). This means that it could be crucial for visually appealing logo designs to be used for new fashion and cosmetic brands. By paying more attention to the visual elements used in these logo designs as well as the elements used in social media posts, a company's products could look more appealing and can shape its brand image into one that not only stands out but attracts more and more people.

Many past research papers have delved into the topic of how visual elements included in logo designs could help attract consumers. In fact, these papers mention the effect many visual

elements in logo designs like color, saturation, value, asymmetry, typography have on consumer perceptions. However, very few mentioned how visual elements included in advertisement posts on social media platforms like Instagram can be used to better market a brand or product. Furthermore, most of these papers did not compare the visual elements used in specific industries like the fashion and cosmetic industries. The past papers covered an overall picture, so the researcher aims to focus specifically on the similarities and differences the fashion and cosmetic industry have when it comes to the usage of visual elements.

During these past few years, social media usage has increased considerably (Moyer, 2022). This has allowed businesses to promote their products on social media, usually with videos and pictures. While logo designs can be helpful in giving a good impression to customers, advertisements are just as important since they can attract more and more people to buy from a particular brand. In addition, since logo designs were the only things mentioned in past research papers, so have the specific visual elements mentioned. Therefore, this research paper will try to pinpoint some of the visual elements used in social media advertisements. Some of the visual elements that may be mentioned are color scheme, alignment, typography, slogans. This list is slightly different from the visual elements used in logo designs.

This research paper aims to answer the question: How can the different visual elements used in logos and in advertisements help with marketing and be used in branding strategies in the fashion and cosmetic industry? The researcher will focus on the visual elements included in logo designs and on social media picture advertisements, excluding video advertisements. The research methodology will employ literature review, marketplace evidence from websites, and along with survey techniques for collection of new data.

If a fashion or cosmetic brand has very appealing visual elements used in their logo designs as well as social media advertisements that stand out and evoke emotions, consumers will be drawn and more convinced to try out the product from that brand. Therefore, businesses can use the insights from this paper to make their current and future businesses in the fashion and cosmetic industry more successful. With a deeper understanding of the role visual elements play in attracting consumers, companies and consumers will not be the only ones impacted, but also future researchers looking for other effective marketing methods. The information gathered from this paper can be used for future researchers to build on what has already been found from other useful insights on the power visual elements have in the fashion and cosmetic industry.

Literature Review

Previous studies discussing the usage of visual elements in marketing focused heavily on how the visual elements in logo designs affected consumer perceptions. This study reviews previous research papers published from 2008-2022.

First, the effect color has on consumer perceptions has been written about very often. For example, Labrecque and Milne (2012) carried out four studies of how color can affect brand personality in the long run. In this paper, the researchers explain how the usage of color affects consumer perceptions which then affects brand personality. They go into detail on how different

hues, value, and saturation levels may cause consumers to feel different levels of excitement and judge a brand's sincerity, competence, and sophistication differently. They also demonstrate that logo shapes influence likability and familiarity as well. Sliburyte and Skeryte (2014) explain how color can have different effects on different age groups, genders, and people who have had different education. The study from this paper found that white, blue, and green are often favorite colors among females while men prefer red more than women. Overall, it was shown that buying decisions may be affected by a consumer's color perception. The papers from Negm and Tantawi (2015) and Sharma and Roy (2021) also discuss how visual elements affect consumer perceptions.

Second, the symmetry of logo designs is also a topic often discussed in previous papers. Luffarelli, Stamatogiannakis, Yang (2019) studied how the level of symmetry, or lack of symmetry, could influence the perceived brand personality and affect brand equity. Similarly, Bajaj and Bond (2018) also study (a)symmetry. They specifically talk about the (a)symmetry in visual brand elements and how this can affect brand personality. It was found in both papers that that logo asymmetry tends to be perceived as more exciting compared to symmetrical logos. However, Luffarelli, Stamatogiannakis, Yang (2019) discovered that logo asymmetry could potentially have a negative impact on perceptions of sincerity, competence, and ruggedness. Third, visual elements can be used in marketing strategies in many ways. Srivastava, Ramakanth, Akhila, Gaikwad (2022) as well as Vyas and Bhuvanes (2015) study the visual elements in package design. Srivastava, Ramakanth, Akhila, Gaikwad (2022) is about package design as a branding tool in the cosmetic industry. This paper explains how packaging design can attract and persuade consumers to buy a product. The researchers mention various design elements like color, shape, images, material, and package convenience. Overall, it has considered package design to be an important element in marketing strategies and to help cosmetic brands to leave a lasting impression. Vyas and Bhuvanes (2015) go into a similar topic but discuss in more detail how packing design elements can impact a user's perception. On the other hand, Hingorani (2008) focuses on the visual elements in skin care magazine advertisements. It was discovered that "skincare ads were always in color (100%), even when a product's colors were black and white" (Hingorani, 2008). So just like with package design, visual elements in skin care magazine advertisements can be just as important.

Lastly, the use of social media to market products has been discussed in research papers by Lee, Hur, Watkins (2018) and Shen and Bissell (2013). The research paper by Lee, Hur, Watkins (2018) investigates "the effect of visual complexity of social media images on consumer's brand perceptions in a luxury fashion context" while the paper by Shen and Bissell (2013) studies how "beauty brands employ social media particularly Facebook, to increase brand awareness and reinforce brand loyalty." Through these papers, it was discovered that "to increase positive perceptions of luxury brands, marketers should determine the visual complexity of social media images they use by determining consumer's degree of familiarity with the brand first" (Lee, Hur, Watkins 2018) and that "Department store brands are more likely to be added

during weekends than weekdays" (Shen and Bissell 2013). Table 1 shows the details of the Literature Review.

Table 1: Literature Review

Study	Research Objective	Country	Methodology	Industry	Factors / Dimensions	Findings
Luffarelli, Stamatogiannakis, Yang (2019).	Examine mechanism underlying how brand personality and logo design can interact to affect brand equity.	U.S.	Quantitative	General	-Logo asymmetry -Brand personality -Brand equity -Logo-evoked perceptions of excitement	- Asymmetrical logos can boost consumers' evaluations and the market's financial valuations of brands with an exciting personality, but not of brands with any other personality.
Ranaweera (2020).	Examine how mere colors featured in brand logos evoke consumer perception about a retailer's eco-friendliness.	USA	Quantitative	FMCG	-Logo color -Color perception -Eco-friendliness Gender	-The high-eco-friendly logo color (green) is perceived as more environmentally friendly -The low eco-friendly logo color (red) is not perceived as environmentally friendly.
Vyas, and Bhuva	The point of focus is how the elements	Global	Quantitative	Fashion	-Packaging elements -Consumer's	-Visual components are more effective

nes (2015)	of the package design affect consumer's perceptions about products and brands.				perception	and influential for packaging design, as they are: 1. noticed by consumers directly 2. communicate quickly at the point of purchase.
Labrecque and Milne (2012).	Examines how color affects consumer perceptions through a series of four studies.	U.S.	Quantitative	General	-Brand personality -Color -Saturation and Value -Package design -incremental effects of color for logo design -Brand personality -Emotions evoked by different colors	-Saturation and value influence brand personality -Saturation and value can be used in conjunction with hue to help determine appropriate brand personality decisions. -Color can affect marketing outcome variables such as purchase intent.
Sliburyte and Skeryte	Theoretical analysis of the problem and explores the	Lithuania	Qualitative	General	-Color perception -Gender, age and education	-Consumers' color perception depends on the demographic

(2014).	peculiarities of the use of color in marketing					factors, although not in all the cases -people of different age, gender and education perceive color differently.
Negm and Tantawi (2015).	Develop a conceptual framework regarding how visual imagery and design in advertising combining the suggestion of consumers about the processing of visual information in advertising.	Egypt	Qualitative	General	-Visual Design Impact on Perception -Elements of design (lines, color, texture, shape, form, value, and contrast)	-Aesthetics and visual imagery are used to: 1.command attention, stimulate curiosity 2.demonstrate product features and benefits, 3. establishes personalities and lifestyles in the minds of the target audience. -Visuals provide information about the promoted matter and connect the images with the meanings that are appropriately

						assigned to the products or services.
Sharma and Roy (2021).	Understanding how visual imagery (aesthetic visual designs and figures) works in advertising to impact consumers' views.	Global	Mixed	General	-Celebrity endorser and consumer attention -Sizes of images -Color -Advertisement tagline and consumer attention	-maximum duration where the respondents focus was on the bright images and the attractive characters rather than content or tagline of advertisements.
Jiang, Gorn, Galli, Chattopadhyay (2016).	Elements of brand logo affecting perceptions of the attributes of a product or company	Global	Quantitative	General	-Mental Imagery and Logo Shapes -Associations Activated by Circular versus Angular Shapes -Effect of shape priming and imagery disposition on company judgment	-A circular (angular) brand logo activated mental associations related to "softness" ("hardness"), and these activated associations subsequently influenced product and company attribute judgments.
Lee, Hur, Watkins	Investigated the effect of visual complexity of	USA	Quantitative	Fashion	-Luxury democratization and social media -Visual	-Participants familiar with a classical style luxury brand

(2018).	social media images on consumers' brand perceptions in a luxury fashion context.				complexity and consumer perceptions -Moderating effect of brand familiarity	perceived that a simple image had greater luxury than did a complex image. -Luxury brands with higher levels of brand familiarity, particularly those that express a classical style, should present images on social media that have fewer complex backgrounds, fewer numbers of the product, and are organized better to obtain desirable results.

Phillips and McQuarrie (2010).	Analyze fashion ads to show how narrative transportation can be a possible response to ads, if specific aesthetic properties are present, grotesque imagery is used.	Global	Qualitative	Fashion	-Color -Mode of engagement -Grotesque imagery -Narrative imagery	-Grotesque imagery was associated with the consumer outcomes of transportation and immersion. These modes of engagement had the potential to be advantageous for brands, as they produced a stronger and more intense brand experience. -Idealized imagery could be problematic for brands because of the potential unpleasantness of identity negotiation as experienced by consumers
Srivastava, Ramakanth, Akhila, Gaikwad	Studies the importance of product packaging in cosmetics branding, and which brands can minimize the gap	India	Qualitative	Cosmetic	-Elements of package design -Cosmetics packaging materials -Consumers' perception -Purchasing decision	-Packaging design is made up of two types of aspects: visual and structural -When shopping for cosmetic

(2022).	between desired brand messages and consumer perception about the brand.				-Color -Typography -Graphics -Size/form	products, it was seen that the consumer had a low level of engagement and hence made many decisions subconsciously or with little inquiry and consideration
Hingorani (2008).	Identify some of the types (or elements) and roles (or functions) of skincare advertising visuals and examine the extent to which they are evident in magazine ads.	Australia, United Kingdom, United States of America, China, India	Qualitative	Skincare	-Skincare Advertising Visuals -Consumer Behavior	- Skincare ads were always in color (100%), even when a product's colors were black and white. -Color ads might be viewed as providing more literal evidence than black and white ads.
Bajaj and Bond (2018).	Explores connections between a fundamental element of visual design, namely symmetry, and consumer	Global	Quantitative	General	-Consumer perception -Visual symmetry -Brand personality -Linking Asymmetry to Arousal	-Brands were perceived to be more sincere when their logos were more representative, elaborate and parallel. -Brands were

	inferences regarding brand personality					perceived to be more sophisticated when their logos were more symmetric and rounder. -Such that brands were perceived to be more exciting when their logos were less symmetric, more elaborate, less parallel or made greater use of the golden ratio.
Shen and Bissell (2013)	This paper initiated an investigation on how beauty brands employ social media, particularly Facebook, to increase brand awareness and reinforce brand loyalty.	France, United States	Quantitative	Beauty/ Cosmetic	-Brand loyalty -Facebook -Viral marketing -Number of Likes vs. Comments on beauty brand Facebook posts	-Department store brands are more likely to be added during weekends than weekdays. -Six beauty brands have neither stopped adding posts about events to their Facebook pages, nor stuck with a particular time to talk about

						events.

Methods

The researcher will be doing secondary research on popular press articles as well as employ literature review methodology to learn about what information previous researchers have found and the opinions they have developed. The researcher has also chosen to do a content analysis that is split into two parts. The first part of the content analysis focuses on analyzing the visual elements used in several social media posts from Instagram that advertise fashion and cosmetic products. Next, it will be analyzing the similarities between different logo designs for some of the most popular cosmetic brands and clothing brands to understand what visual elements were used that could have helped these certain brands stand out. After solidifying the research question and understanding how visual elements are used on social media ads, the second part of the content analysis will be on the survey questionnaire. The researcher will gather new data by sending out surveys to people in her network to see what certain visual elements attract people the most.

(a) Content Analysis

This part of the paper analyzes the way current cosmetic and fashion brands are using their social media accounts on Instagram to sell their products as well as what their logo designs have in common. It is important to know that many of these fashion and cosmetic brands have separate social media accounts for different countries or different topics and the researcher has stuck to analyzing posts from the main social media accounts from these brands. While there are many different visual elements included in these social media posts, the researcher has decided to classify these into 4 categories: color scheme, saturation, typography, and alignment. Moreover, there are many different versions of logos for a single brand. The information below will go into detail on how the specific visual elements are used in social media advertisements as well as patterns the researcher has found in logo designs.

Advertisements: Color Scheme and Saturation

The brands from the cosmetic and fashion industries all have different ways of showcasing their products in an appealing way. The color schemes in cosmetic social media advertisements would often consist of analogous colors as shown in (Appendix Figure 1). These colors are right next to each other on the color wheel. Colors like red, orange, and yellow are examples of a group of analogous colors. Even if these posts do not include exact combinations of analogous colors, they are still considered a combination of analogous colors.

Complementary colors are used in these social media posts as well. Colors like red and green or orange and blue are examples of complementary color combinations. Examples of these are shown below in (Appendix Figure 2). In the images, there are the red-green and orange-blue color schemes. The first image consists of a red bottle with green leaves from the red rose in the

background. The second image includes an orange bottle with the water in the background being a bluish-teal color.

Furthermore, cosmetic products being advertised in a social media post have colors that match with the background color or objects in the background as shown in (Appendix Figure 3). These colors usually are either a lighter or darker shade of the product's color.

Overall, social media posts advertising cosmetic products usually had specific color pairings to enhance their posts. There were also very few black and white cosmetic social media advertisements and instead often had warm colors shown in (Appendix Figure 4). Warm colors are colors like red, orange, yellow, and white (Flanagan, 2019). In the pictures (Appendix Figure 4), colors like red, peach, brown, gold, blue, black, and other colors are seen but the majority of these colors all fall into the warm color category.

On the other hand, the color schemes in the social media advertisements for fashion products were more "random." Within each of the posts, colors were more freely played around with and there were no analogous or complementary color schemes. However, the colors used in the posts always seemed to make the product being advertised stand out. In other words, the colors in the background did not distract the attention from what was being advertised like in the two posts from (Appendix Figure 5).

In the first picture in (Appendix Figure 5), an Adidas outfit is being advertised. With the outfit being bright red with some white stripes and the background being overall very dark, the product is really brought to attention. In the second picture from this figure, the blue Tommy Hilfiger bucket hat is being advertised. The background color for the second picture is a greenish white, matching the white blazer the model is wearing. This brings attention to the blue hat as everything else around it is almost the same color.

There were also more appearances of cooler colors overall (Appendix Figure 6). Cooler colors are colors like blue, green, light purple, and black (Flanagan, 2019). In the pictures, a variety of colors are seen like blue, black, green, yellow, pink, and white etc. However, most of the colors in the posts are in the cool color category.

Lastly, it is clear from (Appendix Figures 1-6) that saturation is high for both cosmetic and fashion advertisements. Saturation is defined as the intensity or purity of a color (Harris, 2023) as shown in (Appendix Figure 7) from dreamhomedecorating.com.

After analyzing posts from both cosmetic and fashion brands, the researcher concluded that they are around the same level of saturation. However, fashion posts have more posts that are completely desaturated in color than cosmetic posts.

Typography

Text was rarely included in the social media posts for both cosmetic and fashion products, but cosmetic social media posts had text more often. When text was included for cosmetic posts, the text was usually put in a place that gives information about the product and still brings attention to the product (Appendix Figure 8). The text was also usually never on top of the people advertising the cosmetic products.

For fashion products, the text would often be an encouraging phrase or the brand's name and written on top of the people wearing the fashion products like in (Appendix Figure 9).

Comparing these two industry's advertisements, fashion and cosmetic social media posts both have text that is "blockier" in terms of font style. The researcher also discovered that white is used very often for cosmetic and fashion advertisements, but cosmetic posts have texts in smaller sizes while fashion posts have larger font sizes.

Alignment

Most of the advertisements for cosmetic products are almost always arranged in a pattern like in (Appendix Figure 10).

When people are included in these cosmetic advertisements, they are usually never far away and are close-ups of the face which is most likely to show the product's effects as shown in (Appendix Figure 11).

Fashion products are advertised differently when it comes to alignment. While cosmetic products are advertised through using close-ups of the face, fashion products are usually advertised by a person showing their whole body like in (Appendix Figure 12).

Logo Designs

Just like with the social media posts, logo designs for fashion and cosmetic brands have their similarities and differences. It is important to know that brands have many different versions of their logos, so the researcher has chosen one version for each brand included in this analysis and has decided to not compare the "color schemes" or "saturation levels" as well. Instead, the researcher will talk about the typography and the symbols in the logo designs shown in (Appendix Figure 13).

Typography is defined as the art that involves arranging a typeface in various combinations of font, size, and spacing (Carton, 2020). Therefore, this section will talk about the similarities both cosmetic and fashion brands have when it comes to their font styles, font sizes, and their alignment or spacing in addition to how these work with the logo symbols.

Logos designs for fashion and cosmetic products are all very different. However, there were still a few similarities. For both cosmetic and fashion logos, the font styles were usually "blocky" font styles meaning that the letters all usually had sharp and straight edges. In addition, many of the logos were in all capital letters. When "and" is included in the logos, the "&" symbol will be used instead. For instance, P&G, H&M, and D&G all use the "&" symbol. Furthermore, font sizes are usually larger than the logo symbols for cosmetic logos. On the other hand, logo symbols for fashion logos are larger than the text. Finally, the alignment of the logo symbol is almost always centered above the text. This can be seen in the following logo designs seen in Figure 13: Unilever, Chanel, Wella, Adidas, Reebok, Banana Republic, Yves Saint Laurent, Versace, Rolex, Louis Vuitton, Michael Kors, Giorgo Armani, Quicksilver and Hermes Paris.

(b) Survey

This survey was conducted completely online through Google Surveys. The researcher first surveyed people by sending the Google Surveys on the Messages app, Discord servers and the subreddit /r/SampleSize as well. Overall, 104 participants responded to the survey. The primary focus of the questions was on studying what visual elements from social media posts and in logos attracted the people being surveyed the most, if at all. The author retrieved both fashion and cosmetic social media posts and included them in the Google Surveys. The Google Survey was split into 3 sections.

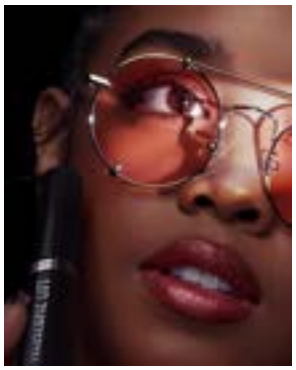
Section 1 focused on the visual elements in social media advertisements. Section 2 focused on the visual elements in logo designs. In Section 1 and 2, there were 2 parts for each, the first part for fashion brands and the second part for cosmetic brands. In these Sections, each question asked the respondent what picture or logo design would influence them to purchase the product from the brand more. Below the question would show two pictures/logo designs, one of the options would show a picture/logo design including the specific visual element mentioned in the question. The other option displayed a picture/logo design without that visual element. For example, in Section 1, a question would ask, "Which advertisement influences you more towards purchasing the product?" and a Section 2 question would ask, "Which logo influences you more towards buying from the brand?" All the visual elements considered in Section 1 are color scheme, saturation, typography, and alignment. On the other hand, the visual elements for Section 2 are font style, size, and alignment. Since the researcher believed that using the same pictures and logo designs for each question would give the most accurate results, the researcher edited each picture and logo design herself.

In Section 3, I asked the respondents for their age, gender, and education (high school, undergraduate, masters, other).

Survey Questionnaire

Note to applicants: Hello! I am a high school student who is currently working on a research paper. This study focuses on understanding the preferences of consumers in the fashion and cosmetics industry. All the pictures and logo designs are either original or modified by the investigator. Please fill out this survey, it won't take more than 10 minutes! Thank you.		
No.	**Question**	**Overall Response (104 responses)**
Section 1: Advertisements This first section of this survey will be on the visual elements in social media advertisement posts. This includes both **Fashion** and **Cosmetics** ads. (**Part 1**: Fashion ads + **Part 2**: Cosmetic ads)		
Part 1: Fashion		

Q1	Which advertisement influences you more towards purchasing the product? **Ad 1:** **Ad 2:**  	**Ad 1:** 42.3% **Ad 2:** 57.7%
Q2	Which advertisement influences you more towards purchasing the product? **Ad 1:** **Ad 2:**  	**Ad 1:** 92.3% **Ad 2:** 7.7%
Q3	Which advertisement influences you more towards purchasing the product? **Ad 1:** **Ad 2:**  	**Ad 1:** 7.7% **Ad 2:** 92.3%
Q4	Which advertisement influences you more towards purchasing the product? **Ad 1:** **Ad 2:**	**Ad 1:** 24% **Ad 2:** 76%

	 	
Part 2: Cosmetics		
Q5	Which advertisement influences you more towards purchasing the product? **Ad 1:**  **Ad 2:** 	**Ad 1:** 93.3% **Ad 2:** 6.7%
Q6	Which advertisement influences you more towards purchasing the product? **Ad 1:**  **Ad 2:** 	**Ad 1:** 86.5% **Ad 2:** 13.5%

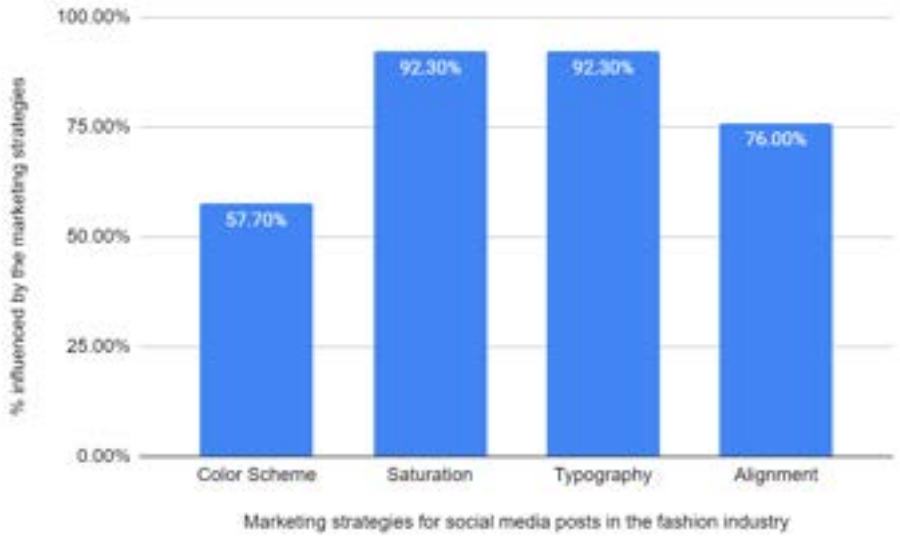
Q7	Which advertisement influences you more towards purchasing the product? **Ad 1:** **Ad 2:**  	**Ad 1:** 1.9% **Ad 2:** 98.1%
Q8	Which advertisement influences you more towards purchasing the product? **Ad 1:** **Ad 2:**  	**Ad 1:** 24% **Ad 2:** 76%
Section 2: Logos The second section of this survey will be on the visual elements in logo designs. This includes both **Fashion** and **Cosmetic** logo designs. (**Part 1**: Fashion logos + **Part 2**: Cosmetic logos)		
Part 1: Fashion		
Q9	Which logo influences you more towards buying from the brand? **Logo 1:** **Logo 2:** NIKE NIKE	**Logo 1:** 97.1% **Logo 2:** 2.9%
Q10	Which logo influences you more towards buying from the brand?	**Logo 1:** 33.7% **Logo 2:** 66.3%

	Logo 1: **Logo 2:** 	
Q11	Which logo influences you more towards buying from the brand? **Logo 1:** **Logo 2:** 	**Logo 1:** 4.8% **Logo 2:** 95.2%
Part 2: Cosmetics		
Q12	Which logo influences you more towards buying from the brand? **Logo 1:** **Logo 2:** 	**Logo 1:** 26.9% **Logo 2:** 73.1%
Q13	Which logo influences you more towards buying from the brand? **Logo 1:** **Logo 2:** 	**Logo 1:** 19.2% **Logo 2:** 80.8%
Q14	Which logo influences you more towards buying from the brand? **Logo 1:** **Logo 2:**	**Logo 1:** 22.1% **Logo 2:** 77.9%

		
Section 3: Personal Details		
Q15	Age	**≥18:** ~24% **<18:** ~76%
Q16	Gender (Female/Male/Other)	**Female:** 69.2% **Male:** 23.1% **Other:** 7.7%
Q17	Education (High School, Undergraduation, Masters, Other)	**High School:** 73.1% **Undergraduate:** 12.5% **Masters:** 4.8% **Other:** 9.6%

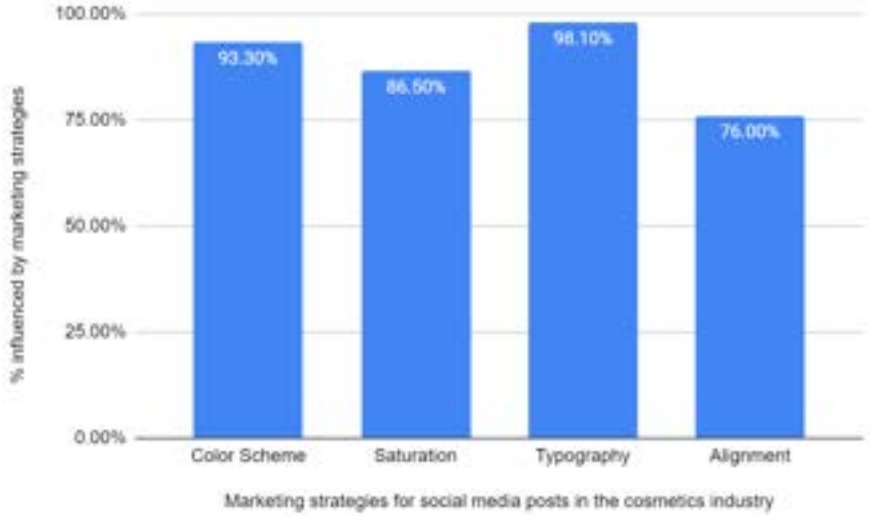
According to the results of the first four questions of the survey that tested social media posts advertising fashion products, 57.7% of respondents chose a post with a color scheme that allowed the product to stand out, 92.3% chose a post that had high saturation, 92.3% chose a post with a white “blocky” font style, and 76% of the respondents chose a post with a more intricate arrangement of the product.

Figure 1: Social Media Posts in the Fashion Industry



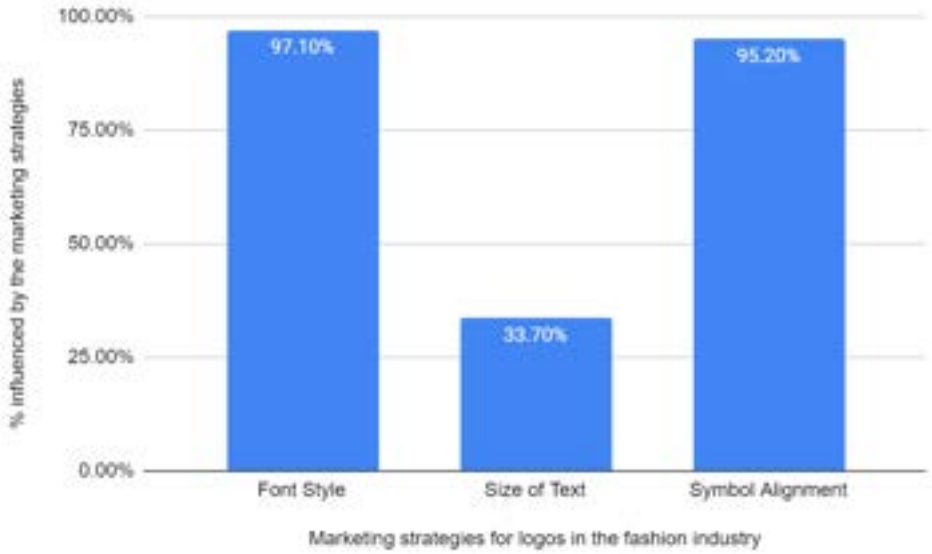
Out of all questions in the survey, question 1 about color scheme had the most mixed responses with 57.7% of people choosing one option over the other. One option had no noticeable difference in colors with everything being overall, very gray. In contrast, the option with a higher preference displayed the product in bright red in contrast to the dark background. This means that this certain color scheme of contrast in colors may not be a significant factor that influences people to buy a product. For both the saturation and typography bars seen in the figure above, a high percentage of people choose one option over the other. The option chosen more for these questions show that certain saturation levels and typography styles are strongly preferred over others. For alignment, 76% of respondents chose the option that had the shoe products lined up in a right to left pattern while 24% of respondents chose the option with the shoes lined up 2 by 2. This implies that more complex patterns are preferred over more “organized” and simple arrangements but may not be as important as saturation and typography elements.

Figure 2: Social Media Posts in the Cosmetic Industry



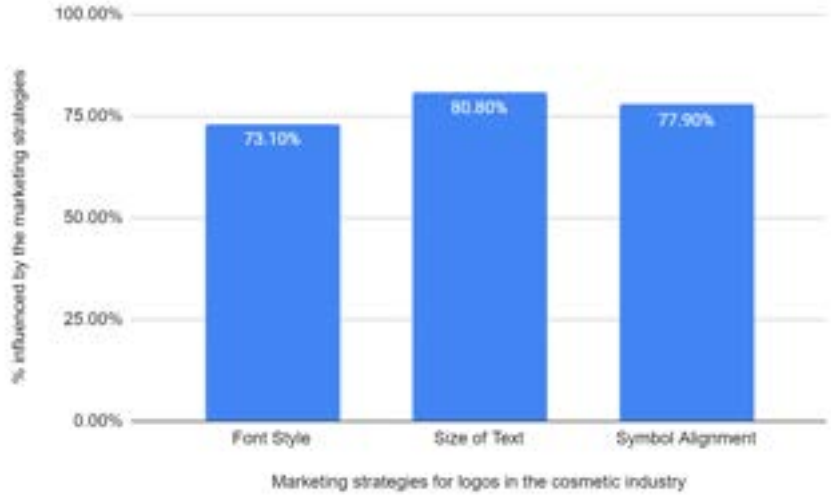
According to the next four questions of the survey that tested with social media posts advertising cosmetic products, 93.3% of respondents chose a color scheme utilizing complementary colors, 86.5% chose a post that had high saturation, 98.1% chose a post with white font aligned around the face, 76% chose a post with more intricate alignment of the cosmetic product. All four questions gave high preferences for one option over the other. However, alignment has the lowest percentage of 76% which is the exact same percentage with the alignment bar for social media posts advertising fashion products. The consistency across both these graphs suggest that alignment holds the same importance in both the fashion and cosmetic industry. In addition, just like with the results in the last figure, saturation and typography both have high percentages showing that overall, the respondents had a strong preference for high saturation and a certain typography style. In contrast to the results in the last figure, a color scheme is strongly preferred over the other. The two options that tested the color scheme had 93.3% of respondents preferring the option showing a complementary color scheme while 6.7% of respondents preferred a non-complementary color scheme which means that color scheme holds great importance in the cosmetic industry.

Figure 3: Logo Designs in the Fashion Industry



According to the next three questions that tested the logo designs for fashion brands, 97.1% of respondents preferred a “block” font style, 33.7% preferred text that was smaller than the symbol, and 95.2% preferred a centered symbol. However, while the respondents did show a strong preference for the “block” font for the Nike brand, which is the original version of the logo, this could have been affected by a past perception of the original logo. Compared to the other bars, the size of text has an unexpectedly low percentage of people influenced by the marketing strategy of having the text smaller than the symbol. This suggests that this marketing strategy may not be a helpful way for brands in the fashion industry.

Figure 4: Logo Designs in the Cosmetic Industry



According to the next three questions that tested the logo designs for cosmetic brands, 73.1% of respondents preferred the font style that was a “block” font, 80.8% preferred font sizes that differed between two words, and 77.9% preferred a centered symbol. All three bars show

high percentages which may mean that the respondents were highly influenced by the three marketing strategies. However, comparing the results from this graph to the previous one, there are many differences. While the last graph showed that 33.7% of respondents were influenced by the "size of text" marketing strategy, this graph is vastly different as 80.8% were influenced by size of text. This may be due to the fact that the last graph involved options that changed the size of text based on the size of the symbol while this graph changes the size of text between two words. In addition, compared to the last graph, the font style and symbol alignment bars are lower by around 30%.

Overall, the results from these three questions suggest that font style and symbol alignment may not influence people as much when these elements are used for cosmetic logo designs compared to fashion logo designs while variation between sizes of words in a logo design is more influential than variation of sizes between text and symbols.

Discussion

The insights garnered from the content analysis, literature review, and survey data helped to understand what the impact visual elements in social media posts and logo designs have in the fashion and cosmetic industries. The information gathered through have been used to develop the framework below.

Challenges

The fashion and cosmetic industries are both industries where many brands are competing against each other. New trends are always appearing due to social media influencers and the world itself. Following the trends in itself is a marketing strategy that many brands follow to keep up with these fast-paced industries. By putting out products that match the rapidly evolving preferences of consumers, only then will new brands be able to have a chance in these intensely competitive industries. In addition, less established brands will still not be able to go against brands that have already found great success and recognition in these industries. However, by following trends, it can be hard for less established brands to stand out. Seamless Source (2019) explains that one of the reasons why clothing brands fail to succeed is because of "lack of authenticity." The article discussed that someone may witness many "small brands [promoting] items such as symbol T-shirts but the likelihood that the T-shirt will sell well is low because there is no design element to it and therefore consumers are unlikely to buy into it unless it has had a heavy amount of celebrity endorsement." However, in such a saturated market, helpful and accessible celebrities are not the easiest to reach. Even if there is a heavy amount of celebrity endorsement, it still may not be promising (Seamless Source, 2019). Furthermore, new brands have not built as much trust and credibility within as many consumers as more established brands. Well established brands already have loyal consumers who would most likely not consider newer brands. As a result, people usually buy products they are already familiar with. In fact, a study found that "(82%) who carried out a shopping-related research task on Google chose a brand that they were already familiar with for their purchase" (Sentance, 2018). So, unless there is something special about another brand that catches a person's attention, they will most likely go with a brand they already know well. In other words, while there are new brands in the fashion and cosmetics industry appearing every year, only a few are commonly used and recognized. These are some of the challenges that not only newer fashion and cosmetic brands face, but also other businesses outside of these industries as well.

Stakeholder Perception

The researcher has pinpointed the customers in the fashion and cosmetics industry as the main stakeholders. The two types of customers that will be discussed are social media users that are exposed to social media posts from fashion and cosmetics brands and people who are shopping in-person in malls, shops etc. to buy fashion or cosmetics products.

1. Social media users

Social media users who are loyal consumers of fashion or cosmetic brands may come across many posts from different fashion or cosmetic brand accounts advertising their products. This could even cause social media users to buy from the brands advertising. According to Salpini, 2017, Instagram has influence on purchase decisions, "with 72% saying they have made fashion, beauty or style-related purchases after seeing something on Instagram." This means that social media can be an incredible tool for attracting consumers and causing social media users to be very important in helping a brand in the fashion or cosmetic industry to grow and expand.

2. People shopping in-person

People shopping in-person for fashion or cosmetics products could also be major stakeholders. For instance, “When shopping for cosmetic products, it was seen that [a] consumer had a low level of engagement and hence made the majority of decisions subconsciously or with little inquiry and consideration” (Srivastava, Ramakanth, Akhila, Gaikwad, 2022). In addition, consumers are most likely looking for products from brands that they are already familiar with. This would make it very challenging for a new brand’s products put in stores to be bought.

Marketing Strategies

The better use of utilizing visual elements in social media posts for active social media users and logo designs for people who happen to be shopping in person can combat the challenges of intense competition in the fashion and cosmetics industry.

1. Social media posts

One of the crucial visual elements used in social media posts is the use of color schemes. While a certain color scheme could allow a marketed product to stand out, it does not necessarily mean it will attract more consumers and convince them to buy the product. However, people may prefer complementary color schemes over color schemes that do not complement each other and further suggests that the use of complementary color schemes can be used as a marketing strategy when using social media as a marketing tool. In addition, brands could make use of higher saturated social media posts to attract more customers instead of black and white posts. This would be especially useful in the cosmetic industry where consumers need to see the effects of makeup products. Certain typography styles could be used more often to market products in both the fashion and cosmetics industry. Most people may prefer “block” fonts and font colors that stand out so companies should implement these in their brands. But above all, brands should prioritize readable, but visually appealing text in their posts. Lastly, alignment in social media posts can be important as well. Arranging products in a more patterned way could interest social media users and therefore attract more consumers. Overall, it was shown that each visual element can be used to please the consumer’s eye. Using visual elements in certain ways can cause consumers to be more captivated by a product and could increase chances for social media users to buy from a new brand.

2. Logo designs

The two visual elements used for logo designs were mainly determined to be typography and symbol usage. People prefer simple “block” fonts over fonts that were rounder or had different thicknesses throughout the letters. So similarly to how text is recommended to be used in social media posts, brands could try making use of more “blocky” font styles. When it comes to alignment, there was a high preference for centered symbols arranged with text. Companies could try putting symbols in other places but maintain centered symbols to help make their logo

designs more attractive and possibly attract the eyes of consumers. However, when it comes to the sizing of text compared to symbols. There is a mixed preference for different ratios of sizes This means that sizing of text compared to symbols may not be a strategy that could be completely helpful for brands to market products.

Impact

By designing more attractive social media posts and logo designs, fashion and cosmetics brands can increase their customer base, increase brand recognition, and create a brand identity that stands out. This suggests that depending on how a fashion or cosmetic brand markets their products using visual strategies, those brands could have different levels of success. Social media posts could possibly increase customer base and attractive logo designs could give a more distinct brand identity. A combination of attractive social media posts and logo designs can increase brand recognition.

1. Increased customer base

Social media advertisements can be the most effective tools to increase customer bases using visual elements like color scheme, saturation, typography, and alignment. Color schemes can be one of the most useful visual elements because it is what people look at the most when judging a product but can also affect different types of people differently (Hallock 2023). Therefore, graphic designers and companies could take more consideration of different color schemes and preferences so they can grow and increase their customer base. For instance, while both men and women prefer blue, many products advertised towards women make use of pink (Hallock 2023). And while some parts of social media posts directed towards women will inevitably have pink, like lipstick for example, the post itself and other products in the fashion industry being marketed do not always need to stick to the pink color schemes and could possibly explore more choices with the color blue. By doing this, brands may seem more interesting and stand out, increasing their chances of growing their customer base. Saturation preferences on the other hand, has been skewed towards the higher saturated options according to the survey. Therefore, brands should continue using higher saturated social media posts to properly display the product's charms as not doing so could make posts less attractive or eye-catching and decrease the chances of increasing customer bases. Typography is also quite important as people may prefer "block" fonts in white for fashion social media posts and "block" fonts in white that share information about the product aligned in a way that does not cover the face for cosmetic posts. Therefore, brands should use these types of elements for the text they put in their social media posts as it will attract social media users more compared to posts that have fonts that may not be as visually pleasing and remove attention away from the product. Lastly, aligning products in a "patterned" way in social media posts is more preferred rather than in ways that are more aligned so brands should look for ways to arrange the products in their posts in more interesting ways that can attract more consumers and increase their customer base.

2. Brand Identity

Logo designs can contribute to making a noticeable brand identity. Logos are the face of a brand and can usually be one of the first things a person sees on a product or the store building (Hales 2022). That is why it is crucial to make sure a logo is memorable but also stands out. These first impressions of a brand can strongly affect consumers' perceptions and how they view a brand. Typography is a very important element in logo designs, which can contribute greatly to brand identity. From font style, font size, alignment of text, and so on, typography can give the brand's name in a way that can affect how the brand is perceived. Although it was shown in the survey that "block" font styles in white are overall more preferred, what is important is that the typography of a logo fits with the brand personality and aims for what their main consumers will like. Another important element in logo designs is the symbols. People have different preferences for the size of symbols but there is a strong preference for the centered placement of symbols compared to text in logo designs. Therefore, taking these preferences in account while also creating attractive symbols can allow a brand identity that resonates with consumers in the fashion and cosmetic industry.

3. Increased brand recognition

Overall, social media posts and logo designs can contribute greatly to expanding brand recognition. With the many fashion and cosmetic brands trying to sell their products, so is the number of social media accounts for these brands. Social media users who are consumers of the fashion or cosmetic industry could have countless posts from brands trying to get their attention. So having eye-catching posts attracting more people can allow larger customer bases to influence how often certain accounts are seen, increasing brand recognition. In addition, logo designs are what people often associate with brands and give the brand a certain image. If there is a special defining feature of a logo design from a fashion or cosmetic brand, people could end up paying more attention to that certain brand. In other words, logo designs can contribute to making memorable first impressions and therefore increasing brand recognition.

Implications

With the growth of the number of social media influencers, cosmetics and fashion products have become more and more popular. As a result, social media platforms are now used as a helpful promotional tool for businesses. Beauty standards and fashion trends have clearly appeared because of increased social media activity (Moyer, 2022). Furthermore, it has also made certain brands and products on higher demand as people will tend to follow the trends on social media and purchase these well-known beauty products advertised.

Consequently, the fashion and cosmetic industries are going to become more and more competitive with the many brands taking advantage of high social media usage. However, it will also make it more challenging for new brands in these industries to attract consumers. Therefore, visual elements can be very useful. Visual elements can be used as a universal language. Like how art can be expressed in similar ways across different countries, the art of visual design can

cut across language barriers and cultural differences. It can evoke similar emotions from people of different backgrounds allowing for a brand or product to reach a larger audience, increasing its marketing potential.

Additionally, logos and advertisement posts are usually looked at very briefly. In fact, an online display ad needs to be visible on a webpage for 14 seconds, on average, for a consumer to gaze at it for one full second (Nanji, 2016). Therefore, having attractive visual elements included in logos and advertisements that could quickly grab people's attention while presenting information in a digestible but still visually appealing way could be crucial in getting more people to engage with the brand and buy the product.

The information and data in this paper can help show how the usage of certain visual elements like color scheme, typography, and imagery in logo designs and advertisements may help to market a brand or product. It may also show what kind of visual elements consumers of cosmetics and fashion products are drawn into. By researching and comparing the visual elements used in past brands in the fashion and cosmetics industry, future brands in these industries can have a better understanding of what will make them stand out and benefit their business.

Limitations and Future Directions

During the process of researching, it is inevitable that some obstacles and limitations may come up. Thus, it is important to address these missing gaps and limitations. One limitation is the lack of network of the author. The Google Forms used for the survey questionnaires in this paper will most likely provide responses from a small number of people and give a lack of data from different age groups other than the "teenager" age group of people around 13-17 years old. As a result, there could be a selection bias where the new data in this paper may be inaccurate and not give a proper representation of everyone in different age groups. However, as a large portion of people who often go on social media and buy fashion or cosmetic products are in this 13-17 age range, the researcher believes that this limitation does not heavily affect the accuracy of research data gathered.

Another limitation is that most of the teenagers who are going to be surveyed are expected to identify as female due to network issues as well. Since women are not the only ones who buy cosmetic and fashion products, it is important to acknowledge that the new data may only reflect people who identify as women and not men. Future researchers can examine this study in different age groups, genders, and with a larger population to ensure more accurate data. The author was able to find several reliable research papers to use for literary review using the Google Scholar search engine. However, the researcher found it challenging to find enough papers that talked specifically about the visual elements used in social media advertisement posts compared to the visual elements in logo designs. So while previous studies had a great amount of information on how certain visual elements on logo designs like color, saturation, value, sharpness of shapes, asymmetry etc. can evoke certain emotions within potential consumers, they mentioned little to no insight on the usefulness of visual elements in the advertisement posts

posted on social media platforms. Therefore, the researcher has decided to not only further the research of visual elements in logo designs, but also dig a little more into the visual elements used in social media advertisements. However, as previously mentioned, the researcher lacked the resources and network to make an accurate and clear picture of how the visual elements used in social media advertisements can help market a brand or product. In the future, researchers with more resources and a larger network can discuss these topics in more depth.

In addition, as the fashion and cosmetics industry is continuously evolving, the information in this paper can become inaccurate in the future. New technological advancements can also cause new visual elements to be created or simply used in different ways. Future designers may also use different programs to design logos and social media advertisement posts. However, this allows future researchers to further explore this topic with the new ways visual elements are implemented in marketing.

Conclusion

This paper has focused on what previous studies did not mention. The aim of this paper was to analyze the usefulness of visual elements in logo designs and social media posts, specifically Instagram, when fashion and cosmetic brands are marketing their products. The research also analyzed the similarities and differences real fashion and cosmetics logo designs and Instagram posts have. Last, a survey was sent out to collect new data and was used to see if certain visual elements used can actually cause consumers to be more eager to purchase a product. The survey respondents were to choose between two social media posts or logo designs that influenced them more to buy the product from a brand.

The paper found that overall, survey respondents had a preference over certain color schemes, saturation levels, typography styles and alignments for social media posts as well as the typography styles and alignment for logo designs. The data analyzed from the survey shows that people prefer balanced color schemes, higher saturations, proper alignment, “block” fonts etc. This suggests that depending on how a fashion or cosmetic brand markets their products using visual strategies, those brands could have different levels of success.

The researcher has proposed a framework explaining the challenges faced by both the fashion and cosmetic industries, the stakeholder perceptions, marketing strategies, and the impact these strategies may have. The framework depicts past marketing strategies found regarding the usage of visual elements and the possible outcomes the strategies have had. Additionally, it highlights some of the stakeholder perceptions on the logo designs and visual elements in social media posts from the fashion and cosmetics industry. It is discussed how these stakeholders are affected and perceive the visual elements used.

The findings in this paper can be used by companies and graphic designers in the fashion and cosmetic industry to help brands increase their customer base/attract new customers, have a memorable brand identity. It can be used as a marketing strategy that will allow brands to standout from others. This paper serves as the base that can allow marketing strategies to be

combined with creativity while also opening the opportunity for future researchers to build on the insights in this paper.

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A Sociocultural Investigation: Embracing Affordable Housing in Essex County, NJ By Jenny Zhu

Introduction

Homelessness is a pressing, complex, global challenge, exacerbated by the lack of suitable affordable housing throughout the United States. As of 2023, around 653,104 individuals are experiencing homelessness, over a 12% increase from 2022, and the highest number since 2007 (Sousa et. al 12). Furthermore, residence in inadequate housing conditions is often linked to sanitation issues, as prevalence of poorly constructed and overcrowded informal housing settlements heightens the risk of respiratory infections and other diseases among vulnerable populations (Habitat for Humanity 1). Even though both governmental and non-governmental organizations have made significant nationwide housing efforts, like the Emergency Rental Assistance and United States Department of Housing and Urban Development (HUD) programs, the scope of the challenge necessitates continued, expanded action. Enhancing the availability of affordable housing will not only improve quality of life for over 650,000 people, but also will foster enduring improvements in communities' societal fabric and intercultural communication.

Situated in northeastern New Jersey, Essex County is home to approximately 854,917 people as of 2021, reflecting a 8.8% increase from 2011 (US Census Bureau; Federal Bureau of Investigation; US Bureau of Labor Statistics n/p). Ranking as the third most populous county in the state, Essex County exhibits a considerably diverse population, encompassing varying racial, ethnic, and socio-economic backgrounds (County Human Services Advisory Council 8). The ethnic composition is 27.2% white, 24.4% Hispanic, 37.5% Black, 5.4% Asian, and 0.1% American Indian (Monarch Housing 7). While the city of Fairfield comprises a mostly white population, East Orange, located in the eastern region of the county, holds predominantly Black population (County Human Services Advisory Council 8). Notably, while the southern and western regions of Essex County hold the wealthiest municipalities, the eastern region serves as a bustling urban hub (County Human Services Advisory Council 8).

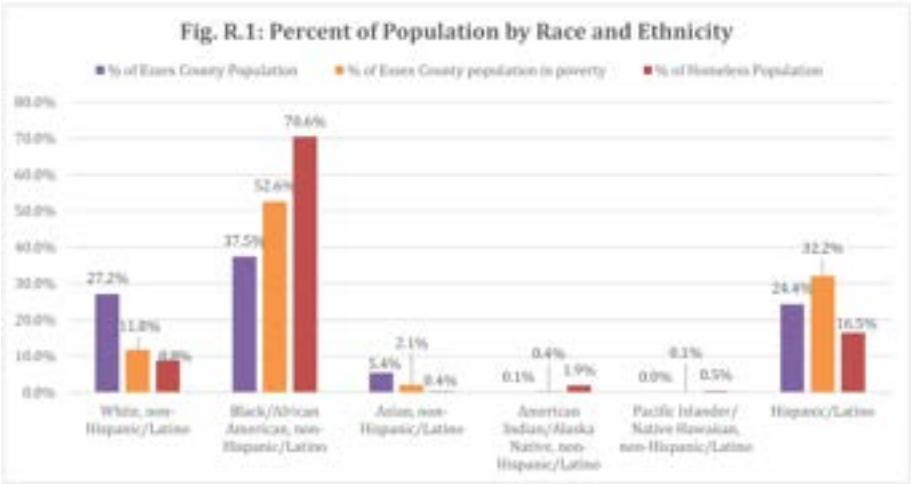


Fig. 1: Percent of Population by Race and Ethnicity. Source: Essex County, 2022.

Home to the highest concentration of African American residents in the state, Essex County is heavily influenced by racial disparities, which can be reflected in community needs. For instance, historical challenges in African American mothers accessing prenatal care have contributed to Essex County ranking fourth highest in the state for the number of uninsured minors (NJ Department of Children and Families 17). As depicted in the figure above, Black/African American individuals comprise 70.6% of the homeless population, representing a substantial proportion of the overall population living in poverty - around 13.8% of all Essex County residents live below the poverty line (Monarch Housing 7). Despite residing in the westernmost affluent region of the county, stakeholders widely agree that there should be improved housing initiatives tailored to address the needs of low-income Black and Latino residents through innovative strategies from state and county governments (County Human Services Advisory Council 19). Central to the overarching objectives of these stakeholders is the pursuit of equitable access to essential services, like housing, for all residents across Essex County.

In Essex County, where the cost of housing exceeds 65% of the national average, the issue of homelessness and affordable housing is a pressing issue that demands a thoughtful and effective response (Best Places n/p). The county holds the highest percentage of New Jersey's homelessness population, nearly 25% (New Jersey Monitor n/p). Affordable housing is a critical step towards bridging the gap between the perceived identity of Essex County and the realities of its diverse population, offering stability and new opportunities to financially strained community members.

Essex County has a comparatively low annual average cost of housing, $91,592, making it the fourth least costly county to live in in New Jersey (County Human Services Advisory Council 21). But, since this data is collated of all housing, rental, and ownership, it is misleading. If all data were equal, the median income of certain areas in Essex County would not be able to afford the increasing costs of living, even if all income pre-tax went towards housing County Human Services Advisory Council 21). Generally, consumers' income that they bring home is a net expense, and they should be contributing no more than 50% of that income towards housing (County Human Services Advisory Council 21). In Essex County, 30% of households are experiencing severe housing problems, due to the fact that they are substantially behind the income required to maintain housing; in fact, this same phenomenon is seen in low-income neighborhoods (County Human Services Advisory Council 21).

In general, Essex County has faced a consistent lack of adequate housing and affordable housing units and opportunities. In 2019, around 25% of households experienced a severe cost burden, spending half or more than half their income on housing (County Human Services Advisory Council 21). With a significant portion of their income going towards rent, these families are not able to afford essential non-housing needs, such as healthcare, education, and food. As of 2019, 30% of households faced at least one of the four severe housing problems: 1) overcrowding determined by high person-per-room, persons-per-bedroom, or unit square

footage-per-person; 2) severe cost burden, 3) lack of kitchen facilities, or 4) lack of plumbing facilities (County Human Services Advisory Council 21). Exacerbated by these severe housing problems, Essex County is roughly behind in the tens of thousands in the amount of housing units needed to meet the housing needs of the residents (County Human Services Advisory Council 18).

According to the 2020 Essex County Needs Assessment, the three greatest concerns pertaining to the housing need are wait lists, education about the availability of services, and barriers around program eligibility (County Human Services Advisory Council 23). It is not uncommon for waiting lists of housing authorities, senior housing, and affordable housing to stretch to thousands of individuals. In addition, landlords may discriminate against having certain program participants in their unit, and the enforcement of all laws is difficult due to limited investigation resources (County Human Services Advisory Council 24). Moreover, a lack of funding and clarity exacerbates the struggle for consumers to find out if they are eligible for housing programs. For these inadequately funded programs, it may be more affordable for tenants to find a different unit (County Human Services Advisory Council 24), especially since each program has its unique eligibility criteria, which may not be communicated clearly to consumers prior to applications. This lack of clarity delays the housing search process until the consumer finds out if they are eligible for a program or not.

As anthropologists, we understand that affordable housing ventures are not just about buildings; it is about the people who inhabit them and the cultures they foster. The affordable housing debate in Essex County is a microcosm of broader societal themes – inclusivity, equity, and the tensions between growth and tradition. Additionally, the lack of affordable housing impacts socio-cultural ties, and influences communities' overall health and well-being. This issue is not only a test for the community's commitment to social justice and inclusivity, but also for environmental justice and urban planning considerations.

This paper will investigate if housing initiatives sufficiently address the needs of the growing homeless population in Essex County, NJ, and nearby areas through informational interviews of governmental and non-profit institutions. Ultimately, I hope to gain insight into affordable housing in Essex County, how it affects community identity, and propose further policy plans.

Primary Causes of Homelessness

Across the United States, homelessness is an urgent humanitarian crisis that requires significant action. Between 2017 and 2022, homelessness has experienced a 6% increase, with chronically homeless individuals reaching a new peak: 127,768 (National Alliance to End Homelessness n/p). Even though initiatives to combat homelessness have expanded, there is still a lack of resources for this growing population, especially among the unsheltered.

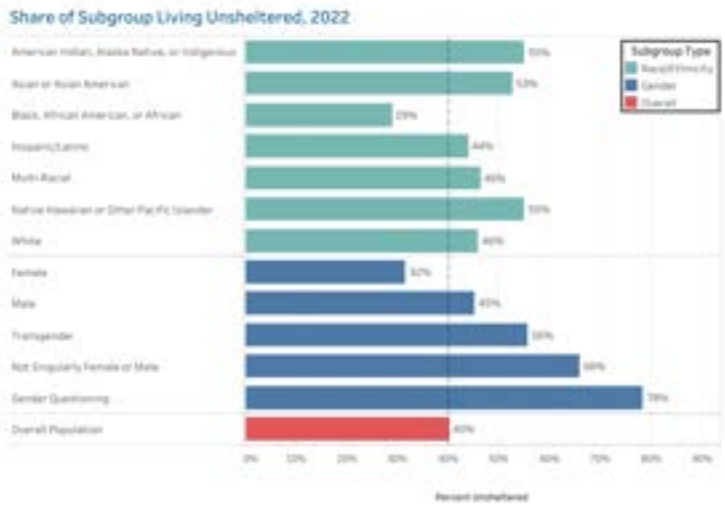


Fig. 2: Share of Subgroup Living Unsheltered, 2022. Source: National Alliance to End Homelessness, 2023.

As seen in the figure above, as of 2022, 40% of the homeless population lives unsheltered, meaning that they have an unsuitable place to sleep at night - a sidewalk, park, abandoned building, etc (National Alliance to End Homelessness n/p). With disparities in the demographics in the unsheltered population, we can conclude that governmental housing initiatives are not equally helping various subgroups. Additionally, homelessness in the United States is largely condensed in urban and metropolitan areas, as homeless population sizes range from 600 to 170,000 across the states (National Alliance to End Homelessness n/p). For instance, California, New York, Washington, Texas, and Florida hold 55% of the country's homeless population, with major cities like San Francisco and New York City facing the highest likelihoods of homelessness (National Alliance to End Homelessness n/p). By urging government investment in these cities with high housing costs, the nationwide affordable housing problem can be mitigated overall.

The book, Paths to Homelessness: Extreme Poverty and the Urban Housing Crisis (1994), explains how "homelessness is not a result of 'faculty people' - those suffering mental illness or alcoholism or from brown homes - or of 'faulty values,' as could be said to be the case with a culture of poverty or homelessness" (Desjarlais 420). Rather, poverty is the main root of homelessness, coupled with the growing lack of affordable housing, especially in urban areas. Additionally, a shortage of well-paying jobs that keep many households and individuals above the poverty line exacerbates housing instability that is likely to lead to homelessness.

Affordability

As a standard, affordability is defined as having households not spend more than 30% of their income for housing, including utilities (Pivo 1 in O'Dell et al.). When families exceed this threshold, especially those of lower-incomes, they may struggle to pay for non-housing needs - food, clothing, transportation, etc. - and thus become cost burdened. This situation, termed

"Shelter Poverty," explains that lower-income households could not contribute 30% of their income for housing and afford basic necessities. It is important to note that if a household cannot afford these necessities after contributing 30% of their income towards housing, it is not because housing is too expensive (Pivo 2). Rather, it might be because either their income is too low, or the cost of their non-housing needs are too high. Nevertheless, rental rates have skyrocketed in various states like New Jersey, with increases of 20-40% in 2023 compared to pre-pandemic (NJ.com n/p).

However, the 30% standard is not the most accurate representation of true housing affordability. For instance, a critique of the 30% standard is that it ignores physical and structural housing conditions (Pivo 2). Additionally, area affordability and local accessibility should be taken into account. Area affordability pertains to the expenses associated with the quality and accessibility of a neighborhood, including factors like school quality, job availability, crime rates, and exposure to environmental risks (Pivo 8). Local accessibility refers to the convenience of having goods and services nearby, enhancing walkability (Pivo 11). To fully capture housing affordability, individuals should take into account location considerations, such as neighborhood quality and accessibility.

To create more affordable housing options, developers might opt for sites in less accessible areas, where residents must rely more heavily on driving, potentially leading to increased car ownership and longer commutes. While this approach may reduce housing costs, it often comes at the expense of greater dependence on automobiles, resulting in various household, social, and environmental drawbacks (Pivo 2013: 10).

Environmental Justice in Housing Construction

For the purposes of my paper, Environmental Justice is defined as "the goal of promoting justice and accountability in environmental matters, focusing on the respect, protection and fulfillment of environmental rights, and the promotion of the environmental rule of law" (Correa et. al 5);" it is crucial in determining where affordable housing construction should take place based on community demographics.

Overall, in the United States, communities of color are exposed to more environmental hazards than white communities. Locally undesirable land uses (LULUS) - landfills, hazardous waste sites, etc. - are disproportionately likely to be found near poor or colored communities (Fahsbender 120). In addition, decision-makers must take into account walkability when deciding affordable housing locations; in New Jersey, residents - around 15-20% out of 340 - have reported problems with using their immediate neighborhoods for physical activity (Greenberg 90). Furthermore, most respondents that faced these challenges were African Americans who lived in "fair" or "poor-quality" neighborhoods (Greenberg 90). So, leaders of affordable housing initiatives must carefully select their construction location, avoiding environmentally sensitive areas such as places with poor air quality and hazardous surroundings.

It is imperative that environmental justice considerations must include the opinions and wishes of all of the community - including marginalized and minority groups. According to a

survey done by UC Santa Cruz, environmental justice concerns such as food accessibility were rated as more important by students of color rather than white students, while white students rated mainstream environmental issues such as biodiversity more important (Lu et. al 2).[64] By sending out surveys or addressing every part of the community, affordable housing leaders can take everyone's opinions on environmental justice into account when making inclusive decisions. On the other hand, lack of input from all residents in a community can lead to poorly designed projects that do not align with the needs of residents.

Gentrification: Affordable Housing's Impact on Community Identity

For low-income communities, affordable housing can serve as a tool for revitalization. Gentrification, the process in which a place, especially a part of a larger city, transforms from being a poor area to a richer one, poses a major threat to those seeking affordable housing (Chong n/p). With increases in property values, housing prices increase, forcing some residents out of the community because of inadequate finances to pay for rent. Forced displacement may leave many people homeless, especially when they do not have the resources to support themselves (Chong n/p). Specifically, lower-income residents who struggle to find affordable housing may cause community segregation as economic inequality rises, putting these individuals in a socially marginalized position (Chong n/p). Anthropologically, gentrification may undermine a community's cultural identity as newcomers may not reflect the existing cultural values and community characteristics, which can negatively affect the social wellbeing of residents.

However, housing developers should also consider the benefits of gentrification when deciding affordable housing sites. Gentrification can increase property values because of the investment in neglected neighborhoods, often making them more appealing, thus making communities more attractive to those looking for a place to live (Chong n/p). Moreover, improvements in infrastructure through revitalization improves parks, schools, hospitals, etc., which increases residents' quality of life (Chong n/p). When businesses become attracted to gentrified neighborhoods and decide to invest, this stimulates the community's economic growth, which in turn can create more job opportunities and foster business development (Chong n/p).

By focusing on gentrifying neighborhoods, leaders of affordable housing initiatives can ensure that long-term residents remain in the community without the threat of rising housing costs, while maintaining community identity and cultural diversity.

Urban Planning

Urban planning goes hand-in-hand with environmental justice when planning affordable housing projects. Firstly, TODs (Transit-Oriented Development) - development that attempts to focus dense residential and retail development around stops for public transportation - are especially important in modern society, with rapid urbanization in large cities and the continued

[64] UC Santa Cruz's undergraduate population was 66% non-white and 43% first-generation during the time the survey was taken.

rise of public transportation use (Noland et. al 130). For those seeking affordable housing or places to live in general, low transportation costs and beneficial transportation alternatives are attractive, which benefits both the user financially and the transportation system (Noland et. al 130). Additionally, inclusionary zoning policies, which require a percentage of new developments to be designated as affordable housing, help distribute affordable housing units throughout communities, consequently fostering more socio-economic diversity (NYC Planning n/p).

Furthermore, urban planners must utilize innovative affordable housing design and architecture that maximizes space efficiency, while minimizing environmental impacts. Since a lack of affordable housing leads to negative consequences for middle- and low-income families, this may lead to overcrowding of limited affordable housing facilities (Emory 1). This situation is known as exclusionary housing, which seeks to limit the supply of affordable housing in a community, as traditional housing methods increase construction costs which drive up housing costs (Emory 1).

Societal Views About Homelessness

Through an anthropological lens, different groups of people may express opposing views about constructing affordable housing shelters in their communities. For instance, older people may be worried about property values and neighborhood stability, while younger people may be more open to affordable housing for diverse and inclusive living environments. In higher-income communities, individuals that prefer a more homogeneous community may be against efforts to achieve diverse racial and economic integration. These views, coupled with the inherent financial challenges in a wealthier community, can lead to segregated residential patterns.

Furthermore, the extent to which residents respond to an affordable housing project in their community greatly affects the community's future character. The phrase "Not in my Back Yard" applies to those concerned about property values, and communities that exclude certain people due to their financial strains, homeless conditions, and minority race (Tighe 21 cited in Ross). Even though there have not been empirical foundations on the link between affordable housing and opposition because of racial prejudice or anti-poor views, community leaders should address racial stereotyping by informing residents on the advantages of welcoming new and diverse groups (Tighe 21).

The issue of affordable housing in the United States can spark controversy when coupled with race and class stereotyping. While affordable housing can benefit historically disadvantaged communities, it may also lead to fear of racial segregation of incoming minority groups. The term "residential segregation" refers to the spatial gap between the rich and poor, which can result in unequal access of resources, employment, healthcare, and education for the poor and minorities. In the 1950s, blockbusting - the practice of introducing African American property owners to all-white neighborhoods to trigger white flight and drive down housing prices (Gaspaire n/p) - exacerbated racial tensions (Tighe 22). Throughout the second half of the 20th century, there has been widespread harassment of minority households, protests against

affordable housing proposals, and blocked school buses that took minority students into white schools (Tighe 22). However, after Barack Obama's presidency, studies have shown that support for segregation and discrimination have declined, but it is still unclear whether some individuals still hold on to previous racial stereotypes, or become more receptive to equality (Tighe 22 cited in Alvarez and Brehm; Clawson and Kegler).

Racial injustice in housing has been manifested in the consistent overrepresentation of Black/African American and Latino individuals in the homelessness population. For instance, African Americans represent 13% of the general population, but are 40% of people experiencing homelessness and more than 50% of homeless families with children (Opportunity Starts at Home n/p). Over the past few decades, racism has been directly linked to racial disparities in housing, with people of color disproportionately struggling to pay rent compared to white households. Since 2021, rents rose by 13.5%, with 58% and 54% of renters being Black and Latino, respectively, compared to the 28% of white renters (Wedeen n/p). Additionally, according to the Harvard University's Joint Center for Housing Studies, Black and Latino renters are twice as likely to be evicted than white renters (Wedeen n/p). Moreover, housing segregation has led to families of color disproportionately residing in low-opportunity neighborhoods, those with low opportunities for upward mobility.

An Ethnographic Glimpse of Homelessness and Affordable Housing in Essex County, New Jersey

Methodologically speaking, to better understand Essex County's affordable housing goals and current initiatives, I conducted interviews of governmental housing administrators and non-governmental affordable housing initiatives. Additionally, I incorporated a survey of the general population that assesses attitudes towards affordable housing and gives an overview of community demographics.

The first specific case study in my paper is the city of Newark, New Jersey. As the largest city in New Jersey, Newark is a vibrant area home to diverse cultures, historic sites, and transportation facilities, such as the Newark Liberty International Airport (Forbes n/p). However, in Forbes report "The Best And Worst US Cities for Renters," Newark is ranked as the #1 worst city for renters across the United States, with a score of 0 out of 100 (Forbes n/p). With the average rent price for a 1-bedroom apartment of $1,348, more than half of Newark households spend at least 30% of their income towards rent (Forbes n/p).

Figure i. Number of Homeless Persons by Municipality and Percentage of County Total						
Municipality	Total Homeless Persons	% of Total Homeless Persons	Sheltered Homeless Persons	% of Sheltered Homeless Persons	Unsheltered Homeless Persons	% of Unsheltered Homeless Persons
Bloomfield	31	1.7%	30	1.7%	1	0.7%
City of Orange	1	0.1%	0	0.0%	1	0.7%
East Orange	51	2.7%	48	2.8%	3	2.0%
Essex Fells	2	0.1%	2	0.1%	0	0.0%
Fairfield	4	0.2%	4	0.2%	0	0.0%
Irvington	43	2.3%	42	2.4%	1	0.7%
Maplewood	1	0.1%	0	0.0%	1	0.7%
Montclair	41	2.2%	34	2.0%	7	4.7%
Newark	1,695	90.6%	1,561	90.7%	134	89.9%
Nutley	1	0.1%	0	0.0%	1	0.7%
Total	**1,870***		**1,721**		**149**	

Fig. 3: Number of Homeless Persons by Municipality and Percentage of County Total. Source: Monarch Housing, 2022.

As seen above, Newark holds over 90% of Essex County's homeless population, with nearly 90% unsheltered (Monarch Housing 11). Mayor Ras Baraka has been working to create a "vibrant, prosperous, and thriving city….ensuring those who need help receive it (City of Newark 3)." Facing a major homelessness setback due to the COVID-19 crisis, Baraka and his administration has increased investment on solutions to ensure that all Newark residents have a safe, stable home. He says, "I believe wholeheartedly that homelessness is a moral issue that demands our greatest efforts to achieve a solution. We need to provide our most vulnerable residents with decent homes and the tools they need to regain control of their lives (City of Newark 3)."

As a progressive mayor, Baraka has declared ambitious housing goals for the city of Newark, aimed to be achieved by 2026 (City of Newark 11). Some of these goals include funding the creation or preservation of 6,600 affordable homes supporting 1,500 new and 200 existing low- and moderate- income homeowners, and supporting 10,000 vulnerable or unsheltered households annually (City of Newark 11).

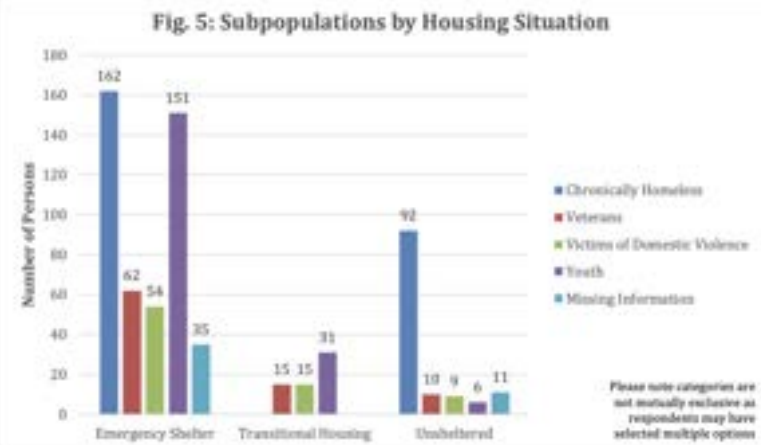


Fig. 4: Subpopulations by Housing Situation. Source: Essex County, 2022.

Throughout Essex County, in emergency shelters, most individuals have been chronically homeless, or are part of the youth population, as shown in the figure above. However, a large

percentage of those unsheltered have been chronically homeless, which suggests that there is either a lack of adequate sheltering and affordable housing options, or individuals are unwilling to receive assistance.

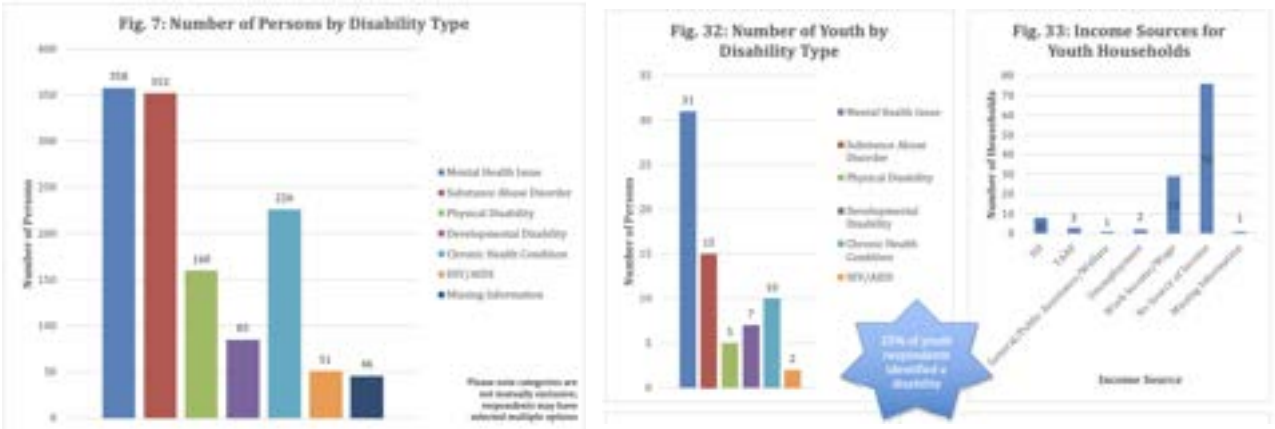


Fig. 5: Youth Housing, Income Sources, and Disabilities. Source: Essex County, 2022.

To better understand current homelessness initiatives in Newark, NJ, I interviewed Brian Park[65], a housing specialist of Covenant House, a youth homeless shelter located downtown. Founded in 1972, Covenant House is a worldwide organization that has fostered 1.5 million individuals between the ages of 18-21 around the world, providing immediate services and beyond. The information I included about Covenant House has two sources: one is the man I interviewed, and the other is the Web to find more information I was not able to obtain through the interview.

Throughout the late 1980s, Covenant House founder Jim White was extremely dedicated to trying to help homeless individuals. In Newark, he noticed that there are many more homeless young individuals, ages 18-21, than many people may think, according to Brian. When people think of homeless people, they do not think of those who are 18-19, which is assumed to be a happy-go-lucky time of their lives. As a result, since the younger homeless population struggles without services, White diagnosed a need to specifically target this age group, thus creating the program model.

In 1989, Covenant House New Jersey (CHNJ) began to provide service to homeless youth through street outreach. Before the shelter with beds was built, the building was a drop-in center, a place that had general supplies. People in need were not able to stay overnight, but could come in for food, towels, paper towels, and warmth; even though in the beginning it was a small initiative, the goal was to form connections with young people and help them. In 1992, Covenant House began to house young people in both their Newark and Atlantic City locations, and in 2000, CHNJ opened their Newark Youth Engagement Center with 45 beds. There is no linear path to the New Jersey Covenant House locations, as people from every part of the world come in, ranging from New York to Florida, to internationally.

[65] To protect the identity of the individual I interviewed, I have chosen to address them through a pseudonym.

Fig. 6: Covenant House, New Jersey. Source: Covenant House, n/d.

During the interview with Brian, he manifested that speaking from the younger demographic, some of the main challenges in the Newark and Union County area faced by individuals seeking stable housing are the availability of low-income housing slots, the availability of permanent housing vouchers, and the rising apartment prices. With apartments costing around $50,000 per year, the bar for being able to sustain oneself is extremely high, and these individuals are unable to afford rent without vouchers. Moreover, without a stable job, it is simply more difficult to find stable housing, and shelters are not fully stable nor safe.

Brian notes that it is common for many homeless individuals to be undocumented, lacking necessary plans like social security and medical insurance; CHNJ helps these individuals with obtaining these documents. When homeless individuals reside in the shelter with addiction or mental health problems, Brian emphasizes how it is not the housing specialists' jobs to cure them, but rather to accept them, support them, and provide them with all the information and services in the area. If someone has challenges that they want to and feel comfortable addressing, housing shelter staff bears the responsibility of helping them find the necessary support services in the area Overall, there is a huge overlap of homelessness in Newark, NJ and mental health issues.

At Covenant House, Brian describes how a variety of staff members ensure holistic support for sheltered individuals, ranging from their behavioral health specialist and housing specialist, to everything in between. Encouraging community involvement, a volunteer coordinator helps bring in people in the area who want to give back and teach the young people about personal finances, economics, home education, budgeting, and current events. Run in the Dove Learning Center, which has a tech lab, art room, maker space, and job application assistance, many residents come in and share their diverse ideas on what might be helpful for the young people, engaging in discussions and exploration groups.

Fig. 7: Bedrooms inside Covenant House. Source: Covenant House, n/d.

At the shelter, there are a limited number of beds: 45. If all 45 are filled, and someone is in need of assistance, Brian told me they are put on the waiting list if they want; in the meantime, Covenant House will refer them out to other shelters that might have a bed: there are plenty of shelters in the area even if they are not specifically youth-oriented. Then, around every week, the front desk specialist makes calls down the waiting list to see if someone would like to come in. Usually, there is a sufficient number of open beds, due to the high turnover.

To assist the transition between sheltered living to a home, Brian emphasized that Covenant House has multiple transitional living programs, like Supportive Apartment Living (SAL), Rights of Passage (ROP), and Nancy's Place. SAL, which has two buildings, is a form of assisted living, where residents pay rent to Covenant House and live in a two-bedroom apartment with another young person. ROP, a low-income housing building, focuses more on helping young people understand what it means to live in an apartment independently with more oversight. ROP residents must be working and contributing a small portion of their income to rent, know how the banking system works and deposit their own checks, and live with others. Lastly, Nancy's Place is a home for young people who have some developmental disability and need more hands-on assistance with living independently.

Even though shelters are not officially partnered with one another, their intercommunication is fostered by the shared goal to reduce homelessness in the area. Regarding governmental collaboration to achieve Covenant House's mission, Brian stated that there are staff who are involved in policy and education, who write grants to get funding/operating money from the government to continue their work; most of the shelter's funding is privately funded though, through donations. Although the Newark mayor is not in direct contact with Covenant House, town officials know that Covenant House is an important player in the area who strives to help homeless youth.

When asked about how an influx of youth has influenced community dynamics in the greater Newark area, Brian was unable to speak on that. However, he emphasized that in terms of North Jersey, Newark is an epicenter of a lot of diverse people, with widespread poverty and homelessness. Site selectors of Covenant House decided that Newark needed a visible, downtown homeless shelter, that is easily accessible by bus routes, and a presence in the city.

Thus, youth from all around the area know that Covenant House is a readily available resource to them, and are always welcome to come for help.

My informational interview was intended to ask people living in the shelter about their experiences and struggles with finding affordable housing, but unfortunately, the permission was not granted.

To better understand initiatives promoting long-term housing solutions, I interviewed Laura Rios-Tober[66], the executive director of the Elizabeth Coalition to House the Homeless, an initiative aimed to serve the immediate needs of the homeless and near-homeless population, and also to provide permanent housing through their transitional programs. As a non-profit organization, Laura notes that the Elizabeth Coalition receives most of their funding through HUD, the United States Department of Housing and Urban Development, which sets limits to specific people with a certain low income level so they can get a leg up. Laura has been serving at the coalition for the past 29 years, and as a long-time resident of Elizabeth, she is an expert in various housing initiatives in Union and Essex County over time.

The Elizabeth Coalition served around 2,500 people last year who are either unhoused or housing insecure, with 78% of them being employed. Despite their employment, Laura notes that their income typically falls between $20,000 and $30,000 annually, which is insufficient for sustainable living, especially after COVID-19. The core issue, according to Laura, lies in the insufficient construction of housing targeting the population in need. She highlights a deficit of 250,000 housing units in New Jersey. As a result, individuals in need go into hotels, but unfortunately, hotels are now catering more towards airport customers. Under an insufficient grant from HUD, the coalition is only able to pay for a limited amount of hotel beds, which forces them to turn down some clients.

The Mount Laurel decision on affordable housing is “a key decision in New Jersey and it chugs everything along for affordable housing,” Laura says. In the Mount Laurel case, during the 1970s, the Christie administration tried to take out the money in the city’s housing trust funds and put it into the general town budget, and Fair Share Housing took them to court. Passed in the 1970s, the court took over Mount Laurel, mandating all municipalities to have a plan for and construction of affordable housing. Mount Laurel was maintained, but Laura mentioned that the court said that cities are cities, and are “doing their fair share in providing housing to the poor,” thus making them exempt from the Mount Laurel law.

Exempt from the Mount Laurel decision, cities are building as much luxury housing as possible before facing government intervention. In Elizabeth, housing is over $3,000 a month near train stations. Cities are now the hubs for housing, since housing near the train and light rail stations allow people greater accessibility if they work in New York City. Laura explains how it used to be that essential workers could work a job and afford a house, but now it is extremely difficult for these workers to pay rent. Thus, some may move to a more affordable home, at the expense of higher transportation costs. Oftentimes, these neighborhoods are food deserts, which

[66] To protect the identity of the individual I interviewed, I have chosen to address them through a pseudonym.

means residents do not have access to a grocery store, fresh produce, and healthy foods. Consequently, households either have to travel further, or eat "dollar store stuff."

When asked for her opinion on whether gentrification is one of the main drivers of homelessness, Laura said that "we all want our neighborhoods to look nicer and we want decent housing for people, but unfortunately, it pushes the rents up in the neighborhoods." The Old Elizabeth General Hospital, which Laura described as ugly and falling apart, was deconstructed and bought by a private equity organization, which has then built luxury housing. Typically charging $2200 a month, these homes have become unaffordable to essential workers, therefore becoming unreasonable for them to live in the area. This issue is exacerbated by certain landlord requirements that disadvantages the vulnerable homeless or near-homeless population. For instance, Laura mentions how landlords may desire homeowners to have a credit score of over 750, and may establish rules that the individual's or family's income is three times the rent.

The Elizabeth Coalition is a nonprofit organization with access to grants. Hoping to lead by example in affordable housing development, the coalition has a strategic initiative to build 50 units of housing in the next five years. Currently, the coalition has some permanent housing that they rent out to those that would most likely be homeless without the homes. Laura says that the coalition gets around 2,500 people a year; although the organization is especially concerned about families, they want to help everyone; overall, the coalition's goal is to get individuals into permanent housing and stabilize the family so they are kept in permanent housing. By providing the necessary support services including transitional housing, outreach programs, community education, and case management, the coalition aims to find individuals housing, a stable job, and sustain housing - all while building resilience. Building resilience may mean finding extra work, Laura says, since "poverty and homelessness walk hand in hand. You cannot say one causes the other. They cause each other."

However, a major setback the Elizabeth Coalition faces is their inadequate funding from HUD, which sets limits on how much the organization can provide assistance. Although the coalition wants to help everyone that comes into their office and does not discriminate, it faces an inability to serve the undocumented population, since HUD standards prohibit it. Last year, the coalition received 6,000 requests for services, and even though around 1,000 are not eligible, they still have to say no to some requests, and help those individuals find other ways of getting housing service.

Regarding community dynamics, Laura emphasizes the moral obligation for municipalities to provide housing for the homeless or near-homeless, even if it is subsidized housing. In New Jersey, most of the poor population are people of color, and some residents have hesitations with having poor people in their communities. "It is almost like some kind of apartheid that we want all the poor to live in the cities, away from us in the suburbs," Laura mentions. "We cannot have a true community without diversity." A major reason why there is a deficit in affordable housing is because "everyone is turning their heads and people do not want to deal with homelessness," Laura says, and there is even "hate for their own neighborhoods who need subsidized housing." This concept of NIMBY fosters a widespread opposition towards

affordable housing initiatives, which makes policymakers hesitant when deciding on affordable housing construction.

In addition, Laura mentions the anti-homeless laws that several towns across New Jersey have employed, criminalizing homelessness and thus marginalizing impoverished individuals. Aiming to remove the homeless from public view, policymakers have prohibited the homeless to sleep outside and for residents to feed the poor. Laura shares one town's message towards refugee treatment: "Don't even give them a bottle of water. We want them to feel unwelcome." Furthermore, Laura describes how towns would make up excuses to "cover up" the fact that they are segregating against the poor, saying that the community is unable to provide adequate services to them because of limited land, or the community implements different zoning regulations to exclude the homeless. "That's why we have the Mount Laurel Law, because they were zoning out the poor," Laura states. Lastly, she explains how the Elizabeth Coalition works with policymakers directly up to a certain point, but ensuring that the coalition keeps to their principles and overarching goal. "Whatever it takes, we will do. We'll either work with you or just do it," Laura claims, "No one should be homeless in America."

Then, I interviewed the Executive Director, Mary Smith[67], of the Saint Joseph's Social Service Center, the sister organization of the Elizabeth Coalition. Founded in 1986, Saint Joseph's provides immediate basic needs such as food, medication, clothing, and a wide range of services and programs to the materially poor and homeless community in Elizabeth and the greater New Jersey area. Mary emphasizes the importance of accessibility in vulnerable populations, by which every individual should have equal access to basic human necessities. To help children, Saint Joseph's provides students with school supplies, and toys around Christmas.

Saint Joseph's is a non-governmental organization that is privately funded through individual donations. Mary estimates that there are 2,500 individuals on the Saint Joseph's mailing list, the organization requests funds from different foundations, and Saint Joseph's hosts various fundraisers. In their charity donations program, Saint Joseph's accepts new clothing items. Connected to nearby parishes, Saint Joseph's has been financially supported by the Little Flower Church and the Our Lady of Peace Church in Berkeley Heights, NJ.

When inquired about the demographics of those seeking assistance from Saint Joseph's, Mary observes a notable shift over time. Previously, the clientele comprised a distribution of 50% American-born individuals, and 50% immigrants, all of which were economically disadvantaged. However, in more recent years, approximately 75% of those seeking aid are immigrants, primarily coming from South American countries. There are a small number of totally homeless individuals, but many are extremely vulnerable to homelessness because of the lack of affordable housing and their meager wages. Despite some maintaining employment, Saint Joseph's emphasizes prioritizing rent payments to secure stable housing, recognizing the pivotal role it plays in accessing other vital services.

Regarding the different services Saint Joseph's offers, they have four food programs, kids programs, adult learning programs, health services programs, and more. Their "Daily Bread"

[67] To protect the identity of the individual I interviewed, I have chosen to address them through a pseudonym.

program provides food and sandwiches Monday through Saturday, and is open to all. The Saturday Soup Kitchen is a weekly hot meal, like eating at a restaurant. “Whatever we have, we share,” Mary says, “We do everything with as much dignity as possible.” Additionally, programs available to registered clients include a monthly food pantry program, which provides a full bag of groceries, protein, and produce, health services program, and seasonal programs. For their food program, there are thousands of individuals in their database, serving around 900 unique households with at least one month of food last year, according to Mary.

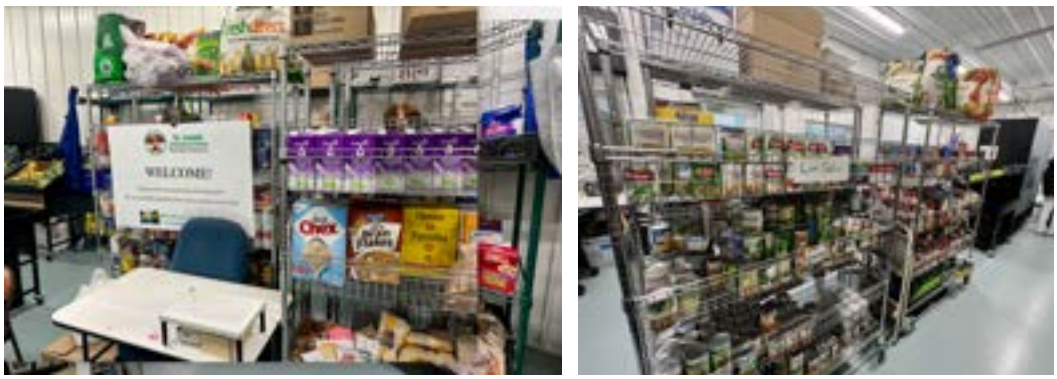


Fig. 8: Saint Joseph’s Food Pantry. Image by Jenny Zhu, 2024.

Mary emphasizes how Saint Joseph’s is extremely grateful for their large numbers of volunteers that help on-site in their soup kitchens, or outside of the service center. According to Mary, there are around 6,000 volunteers in total (which includes one-time volunteers) with around 100 on-site; Mary has even seen four generations of families helping in the soup kitchens. On the other hand, there are only five full-time and five part-time workers, but they are close-knit and sufficient to fulfill the work demanded. However, Mary says that Saint Joseph’s does not partake in a ton of outreach. Most people have heard about Saint Joseph’s, but not about their holistic services; for instance, some people thought that Saint Joseph’s was only a food pantry. Mostly, clients line up on the sidewalk.

Concluding my investigation of understanding different affordable housing initiatives, I conducted an interview with Diana Brown[68], the Executive Director of the Supportive Housing Association of New Jersey (SHA). Founded in 1998 as a statewide non-profit trade organization, SHA’s mission is to promote and maintain a strong supportive housing industry, serving people with special needs. The SHA is composed of 110 member organizations engaged in either affordable housing construction or service provision. According to Diana, SHA serves as a pivotal nexus for organizations, offering support to enhance their capacities and advocating for policy reform. While SHA itself does not directly deliver services to clients, its active involvement in policy discussions spans beyond Essex County, encompassing the entirety of New Jersey. Diana emphasized the importance of recognizing individuals’ multifaceted identities, since “people are multidimensional.” Diana noted that a challenge with this idea is that

[68] To protect the identity of the individual I interviewed, I have chosen to address them through a pseudonym.

SHA's funding is often in very discrete pockets, which makes it difficult for the organization to provide all needed services efficiently.

When asked if SHA's member organizations sufficiently address the diverse needs of the homeless population, Diana said, "Sufficiently is an interesting word. I do not think we are sufficient in any way." She highlighted how the need for diverse services vary depending on time and trends. Currently, for instance, high rents are heavily influencing people looking to find stable housing, and although Diana ensures that SHA's member organizations work very hard to provide adequate services to their clients, she noted how "it is never going to be sufficient." Specifically, high rents and housing costs are impacting individuals because even if they receive support in the form of vouchers and rental assistance, they still face the challenge of finding an apartment unit that they can rent within the voucher guidelines of the program. The biggest challenge, according to Diana, is to find landlords accepting the vouchers, the help, and the people within a payment standard, which is defined by HUD and other organizations, "but it is almost like [HUD and other organizations] cannot keep up."

SHA works with homeless shelters in Trenton and other cities and with organizations that provide supportive housing. Even though shelters are a crucial doorway to help people come in off the street and to have a temporary roof over their head the SHA wants to get these individuals to the next step to find a home for rent or purchase. In New Jersey, Diana explained that there is a best practice across the nation policy known as Housing First, meaning "let us get that person into a permanent housing situation first, and then we will deal with their needs because then they can have space and safety, where the environment will be better for them to address their needs because their in permanent housing."

In New Jersey, Diana noted that there are a couple of important legal cases happening. Firstly, there was the passed landmark legislation at the end of March 2024 to create more affordable housing. In the press release of Fair Share Housing, SHA was featured as part of the network and a major influence on passing the legislation by bringing more service partners to the table with organizations that work with specific groups like mental health, thus broadening their coalition and showing support from a wide variety of people. The second big thing is the landmark case in the Supreme Court regarding the criminalization of homelessness. There has been a movement in towns to arrest people sleeping on park benches because those individuals have nowhere else to go. The SHA will be part of an amicus brief in the Supreme Court, where they will be named along with other partners, as supporting the non-criminalization of homelessness. "If they lose it," Diana stated, "what you will see is just people jailing people."

In the past, Diana shared how the SHA has tremendously influenced policy. For the past 25 years, the SHA has been part of a homelessness and the Olmstead v. L.C. decision, which is a lawsuit describing how people with disabilities should not be locked up into institutions. That landmark decision, the Supreme Court said, is that "[individuals with disabilities] have a right to be held in the least restrictive setting," meaning they do not get locked up in institutions if there is a better way to address the problem. Diana emphasized that this has resulted in the entire

supportive housing movement, in the sense that people could live in communities with the right supports, and live meaningful lives in the communities.

For the purposes of this paper, I also gathered ethnographic data through a survey I conducted with people all around New Jersey to gain some demographic information and societal views on the importance of diversity and inclusivity in their communities, with regard to homelessness and affordable housing initiatives. The survey was completely anonymous, and answering all questions was encouraged but not required. The survey asked the following questions:

1. What town and county do you live in?
2. What is your race or ethnicity?
3. How old are you?
4. Are you a US citizen? If not, please state your citizenship or immigration status.
5. How long have you lived in your town?
6. On a scale from 1-5, how satisfied are you with the socio-cultural dynamics, like diversity and inclusion, in your neighborhood?
7. How concerned are you with homelessness and building affordable housing units in your community?
8. How open are you to welcome new and diverse racial or ethnic groups to your community?

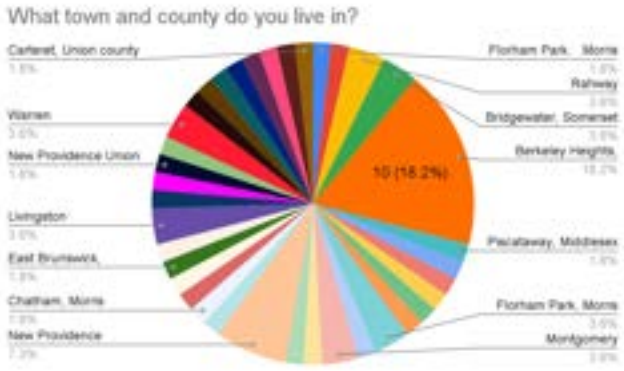


Fig. 10: Town and/or county of respondents.

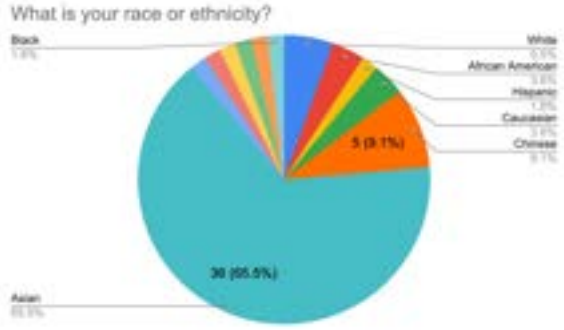
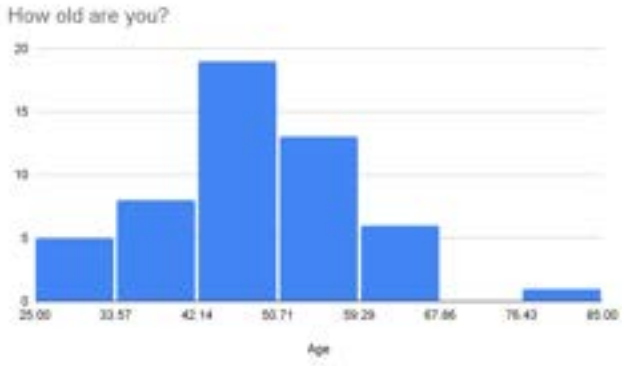


Fig. 11: Respondents' Race/Ethnicity.



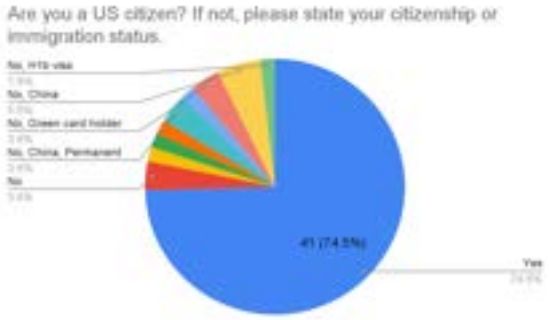
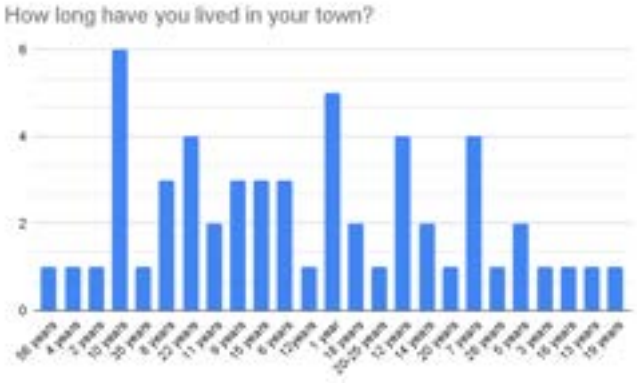


Fig. 12: Respondents' Ages.

Fig. 13: Citizenship Status of Respondents.



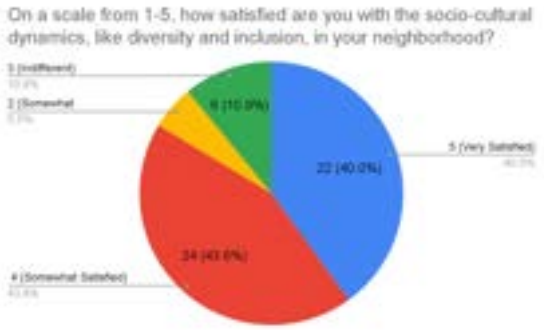
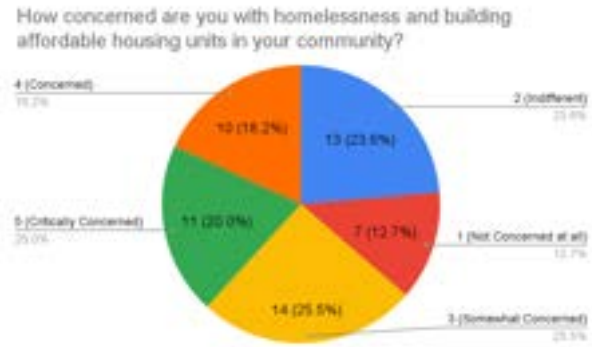


Fig. 14: Length of Residency of Respondents.

Fig. 15: Satisfaction of Socio-Cultural Dynamics.



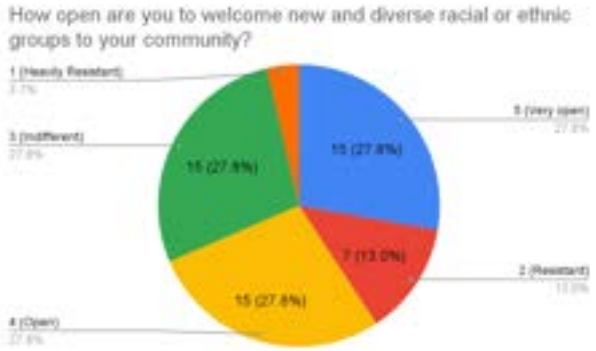


Fig. 16: Concern for homelessness and affordable housing.

Fig.17: Openness to Diversity.

With a total of over 50 respondents, I was able to gain a glimpse of residents' views on affordable housing initiatives and possible correlations with demographic information. First, as shown in Fig. 10, many of the respondents live in Berkeley Heights and New Providence, neighboring towns in Union County. Even though over 80% of respondents were Asian, according to Fig. 11, this statistic may not be fully accurate due to survey methods. Nevertheless, towns like New Providence hold a large, growing Asian population, comprising the second-largest racial group in the town: 16.4% (World Population Review n/p). Similarly, although almost three-quarters of respondents were US citizens, as shown in Fig. 12, a large sum of those who were not were Chinese citizens, which can be attributed to the large proportion of Asian respondents. Fig. 12 highlights the ages of respondents, and according to the data, most respondents were in the age range of 42-59, which attributes to the distribution of the survey mostly to parents of teenagers. From personal relationships, many of the respondents are of the middle-class and work a 9-5, adequately paying job. As shown in Fig. 14, the length of residency of respondents in their respective communities varies greatly, with 10 years being the most common. The data in Figs. 14 and 15 demonstrate that even though most respondents were satisfied with socio-cultural dynamics within their communities, many are still welcome to diversity in their communities. However, according to Fig. 16, there is not a high level of

concern for homelessness and affordable housing construction in respondents' communities, as there is an even split between the lower end (1-2) and the higher end (4-5). Lastly, Fig. 16 shows that most respondents were indifferent, open, or very open to diversity.

Conclusion

In conclusion, this paper sheds light on the intricate relationship between affordable housing initiatives and socio-cultural dynamics within Essex County, NJ, while also delving into their reflection of community identity. Through a thorough examination of various perspectives about homelessness, affordable housing, and diversity, it is evident that affordable housing initiatives play a pivotal role in shaping the fabric of Essex County's communities.

In Essex County and nearby areas, there have been substantial initiatives geared towards certain subgroups of the large homeless population. Specifically in Newark, a Covenant House has provided focused support towards the youth homeless population with temporary housing. In the greater Essex and Union Counties, the services provided by the Elizabeth Coalition coupled with St. Joseph's Service Center has allowed holistic support for homeless individuals, ranging from immediate needs like food to long-term goals like homeownership and job stabilization.

These initiatives not only address the pressing issue of homelessness but also serve as a catalyst for positive socio-cultural change. By providing stable housing options, they contribute to the creation of cohesive and vibrant communities where individuals from diverse backgrounds can thrive. Additionally, affordable housing initiatives reflect the resilience and inclusivity of Essex County's community identity, emphasizing the importance of ensuring housing equity for all residents.

However, it is clear that there is still work to be done. Despite the progress made through existing initiatives, challenges such as limited funding, rising rental prices, and lack of well-paying jobs persist. Moving forward, leaders of affordable housing initiatives, local policymakers, and stakeholders must continue to collaborate and innovate in order to develop comprehensive solutions that address the multifaceted needs of Essex County's population.

This research underscores the critical importance of affordable housing initiatives in shaping socio-cultural dynamics and reflecting community identity in Essex County, NJ. By building upon the insights gained from this study, it is our hope that future policy plans will be informed by a deeper understanding of the nuanced intersection between housing, culture, and community in this dynamic region.

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Strategy, Stalemate, and a Shattered Europe: The Legacy of the Schlieffen Plan and the Invasion of Belgium By Christina Zhang

"The nations slithered over the brink into the boiling cauldron of war without any trace of apprehension or dismay", former British prime minister David Lloyd George once wrote in his Memoirs.[69] This later retrospection of World War I encapsulated the cataclysmic effect of the conflict, which significantly reshaped the trajectory of European history and global power dynamics.

The foundation for the eventual onset of World War I involved an intricate web of alliances and oppositions that built up for decades. Prior to the world war, there had been an ongoing tension between two international military coalitions - the Allied and Central Powers. The Allied Powers, interchangeable with the Triple Entente, consisted of the United Kingdom, France, and Russia. Whereas the Central Powers, or the Triple Alliance, was made up of Germany, Austria-Hungary, and Italy.[70] Established as diametrical rivals, the two powers sought to dominate each other in every warfare. Hence, what initially started out as regional disputes eventually snowballed into the global level World War I.

Two important factors - nationalism and militarism - played a huge role in inciting actions of the Allied and Central Powers in relation to the Schlieffen Plan and the invasion of Belgium, which contributed to the escalation and outbreak of World War I. One of the inaugurating events was Austria-Hungary's annexation of Bosnia and Herzegovina in 1908, which heightened tensions with a neighboring Allied power, Serbia.[71] The subsequent assassination of Archduke Franz Ferdinand in 1914 by a Bosnian-Serbian led to more disputes between the two nations.[72] Ultimately, European nations had to align themselves to different sides of the Allied and Central powers. Driven by its nationalistic desire for expansion and dominance in Europe, Germany believed that "the onset of war and its support of

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[69] Brands, Hal, and Charles Edel. 2019. "How Woodrow Wilson Lost the Peace." The American Interest. January 30, 2019. https://www.the-american-interest.com/2019/01/30/how-woodrow-wilson-lost-the-peace/

[70] Little, Becky. 2022. "How a Regional Conflict Escalated into World War I." HISTORY. A&E Television Networks. February 4, 2022. https://www.history.com/news/regional-conflict-world-war-i-beginning.

[71] Kiger, Patrick J. 2021. "8 Events That Led to World War I." HISTORY. April 6, 2021. https://www.history.com/news/world-war-i-causes.

[72] Kiger, "8 Events That Led to World War I."

Austria-Hungary was a way to secure its place as a leading power".[73] Hence, Germany offered Austria-Hungary a "blank check" assurance; that is, an "unconditional support" for Austria-Hungary's military decision.[74] Originally, the conflict might just stay localized; nonetheless, Germany's intervention emboldened Austria-Hungary to wage war on Serbia on July 28 of 1914, turning a supposedly Balkan war into a European one.[75] Russia, due to its cultural ties with the Slavic populations in Serbia,[76] along with its national interest in gaining strips of Balkan lands,[77] had decided to back Serbia up for military support. Even though the Russians considered their military mobilization as a precautionary measure, the Germans interpreted it as an explicit sign of war.[78] Consequently, on July 31st, Germany issued an ultimatum saying that Russia must disband its forces at once,[79]but the Russians refused to comply with the stipulations and propelled the Germans to officially declare war on August 1, 1914.[80] Soon after this, France was brought into the conflict, too. This is mainly because of its expansionism and imperialism race against Germany. According to Richard Fogarty, the French saw its "pursuit of empire could only come at the expense of the German pursuit of empire".[81] Thus, in order to settle this long-term hegemonic antagonism, France entered the war on 3 August.[82] Meanwhile, the third nation of the Triple Entente, Britain, is constantly being pushed

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73 Norwich University. n.d. "Six Causes of World War I | Norwich University - Online." Online.norwich.edu. https://online.norwich.edu/online/about/resource-library/six-causes-world-war-i.

74 Norwich University. n.d. "Six Causes of World War I | Norwich University - Online."

75 Imperial War Museums. 2018. "How the World Went to War in 1914." Imperial War Museums. 2018. https://www.iwm.org.uk/history/how-the-world-went-to-war-in-1914.

76 Levinson, Martin H. 2014. "Ten Cautionary Gs Lessons from World War I." ETC: A Review of General Semantics 71 (1): 41–48. https://www.jstor.org/stable/24761886?seq=3.

77 "World War I." n.d. Tom Jacobson.tripod.com. https://tomjacobsen.tripod.com/OnlineLectureSeries/Burson/ww1.htm.

78 Ibid.

79 Ibid.

80 Ibid.

81 Little, Becky.. 2022b. "How Imperialism Set the Stage for World War I." HISTORY. HISTORY. March 7, 2022. https://www.history.com/news/imperialism-causes-world-war-i.

82 Imperial War Museums. 2018. "How the World Went to War in 1914." Imperial War Museums. 2018. https://www.iwm.org.uk/history/how-the-world-went-to-war-in-1914.

by Russia and France to declare war on Germany. After a series of negotiations, Britain contemplated its priorities between maintaining a balanced power and staying at peace, and deterring Germany's increasing authority in Europe along with threats to Britain's "industrial and imperial supremacy".[83] Eventually, Britain decided to prioritize the latter, and on August 1, it mobilized its navy through the English Channel to counter the marching of German soldiers on French lands.[84] Following that, Britain also agreed to enter the war if Belgium was invaded, as it had an obligation to protect its neutrality according to international law.[85] Supported by the words of Sir Edward Grey: "On account of Belgium, whose neutrality is violated, must peaceful England go to war".[86] Realizing itself in a difficult position of having to fight against both Russian and French fronts, Germany devised the Schlieffen Plan to strategically win the war and avoid having to fight two fronts. The Schlieffen Plan emphasized how German troops should first advance north through Belgium to defeat and gain control over parts of France like Paris; then shall redistribute a number of troops to confront Russia, thus avoiding fighting on two fronts simultaneously.[87]

Under the interplay of nationalism and militarism, European hegemonic rivalries divided themselves into alliances and fiercely defended their national interests. While the German Schlieffen Plan and its invasion of Belgium were just one part of the strategic warfare among the many wars fought during the time period, they were considered a significant turning point in history. The failure of the Schlieffen Plan not only marked the inception of World War I, but also resulted in military, political and humanitarian disasters that would keep the European landscape fragmented for many years to come.

The Schlieffen Plan was created by Alfred von Schlieffen in 1905.[88] Schlieffen was an experienced officer who had fought in both the Austro-Prussian War and the Franco-Prussian War, and served as Chief of the General Staff of the German Army. Schlieffen was adept in devising military blueprints, including "defensive, offensive, and counter-offensive

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83 Ibid.

84 Ibid.

85 Ibid.

86 "THE NEUTRALITY of BELGIUM ITS ORIGIN and VIOLATION." n.d. https://cudl.colorado.edu/MediaManager/srvr?mediafile=MISC/UCBOULDERCB1-58-NA/1508/i73335137.pdf.

87 Mombauer, Annika. 2019. "What Was the Schlieffen Plan?" What Was the Schlieffen Plan? March 1, 2019. https://www.open.edu/openlearn/history-the-arts/history/what-was-the-schlieffen-plan.

88 "GHDI - Document." n.d. Ghdi.ghi-Dc.org. https://ghdi.ghi-dc.org/sub_document.cfm?document_id=796.

campaigns".[89] The Schlieffen Plan was another such counter-offensive strategy. Schlieffen acknowledged the fact that Germany would be outnumbered fighting in a two-front battle, so the purpose of the plan was to conduct a 'blitzkrieg war' on one front and then confront the other without being encircled. According to Zuber, the original plan was to leverage Germany's "interior position and rail mobility" to launch a counter-offensive against one front, that is either France or Russia, depending on the military circumstances at that time. Then, after having defeated the first force, Germany would reposition and redirect the remaining troops to launch another attack on the other front.[90]

Alfred von Schlieffen soon retired and was replaced by Helmuth von Moltke the Younger as the General Staff of the German Army in 1906.[91] Consequently, Moltke also took over the Schlieffen Plan and made modifications to it that later gave rise to Germany's military debacle and the First World War. There are three main reasons the plan failed. First is Moltke's untenable modification of Germany's offense-defense balance. According to Belil, in contrast to Schlieffen's view on how a counter-offensive strategy would have served Germany the best, Moltke decided on a more extreme offensive plan - that is to gain "an overwhelming advantage in the balance of forces" and to overcome its enemies' advantages in defense.[92] He also believed that a more offensive strategy relying on "initiative, surprise, and speed" could make up for a significant 30% reduction in troop numbers.[93] Therefore, instead of deploying an ideal 48.5 corps to flank French forces through Belgium, Moltke decreased the number of corps to 34.[94] This reduction in troops was insufficient for Germany to win the battle. According to Kauffner: "A successful offensive requires that the attacker have a significant advantage in terms of firepower or something else",[95] and Germany evidently had none. Hence, Moltke's reasonable alterations to

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89 "The Schlieffen Plan | History of Western Civilization II." n.d. Courses.lumenlearning.com. https://courses.lumenlearning.com/suny-hccc-worldhistory2/chapter/the-schlieffen-plan/.

90 Zuber, Terence. 2002. "Schlieffen's War Plan, 1891–1905." *Oxford University Press EBooks*, October, 135–219. https://doi.org/10.1093/acprof:oso/9780199250165.003.0004.

91 "GHDI - Document." n.d. Ghdi.ghi-Dc.org. https://ghdi.ghi-dc.org/sub_document.cfm?document_id=796.

92 Belil, Michael. 2018. "The Strategy Bridge." The Strategy Bridge. February 2018. https://thestrategybridge.org/the-bridge/2018/2/1/a-re-examination-of-the-schlieffen-plan.

93 Ibid.

94 Ibid.

95 Kauffner, Peter . 2024. "The Schlieffen Plan and a Two-Front War." Www.militaryhistoryonline.com. 2024. https://www.militaryhistoryonline.com/WWI/SchlieffenPlan.

the original plan had resulted in Germany's defeat by the Allies.

A second reason for the failure of the Schlieffen Plan is its logistical and operational inadequacy. Stated by Major Craig O. Petersen, in order to defeat France and Belgium in the first front, it was crucial for Germany to effectively and fully utilize railroads as a source of supplement of provisions for the marching troops and a swift "disembarkation" from Belgium to the second front in preparation for the battle against Russia.[96] Nonetheless, the Schlieffen Plan lacked in logistics consideration, as it assumed that the railways were under German control. This was refuted by Petersen, who further noted that instead of the Germans receiving adequate organic transports to troops and redirecting their counterattacks using the railway system, "it was the French and Belgian forces that capitalized on and utilized the strategic mobility provided by the interior railways to bring up large reinforcements, thus enabling the French to stall the German turning movement".[97] Later when Germany tried to retreat, they found out the French had destroyed the railway system beforehand, leaving them to march on foot and weakening their forces against Russia.[98] In essence, Germany's inability to leverage the railway as a line of communication and transportation led to its disadvantaged position during the invasion of Belgium.

Another external reason for the failure of the Schlieffen Plan was the unexpected resistance from Belgium, France, Britain, and Russia amidst German invasion. Initially, Germany did not anticipate any resistance from Belgium itself. However, a total of 200,000 Belgian soldiers fought fiercely and managed to gain more time for its allies to mobilize their armies.[99] Moreover, Germans who once envisaged a successful deterrence against France were quickly disheartened at the Battles of Marne, for their 1st Army was met by 150,000 French troops and their 2nd Army was met by another 6000 French men.[100] Additionally, the Schlieffen Plan severely underestimated the British Expeditionary Force (BEF) in defending Belgium. Realizing that Germany had broken Belgium's neutrality, Britain sent 100,000 soldiers to assist Belgian resistance, which, according to Petersen, resulted in "lengthy delays from the Schlieffen plans prescribed six week movement".[101] Finally, the Russian mobilization was faster than

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96 Petersen, Craig. 2008. "The Schlieffen War Plan: What Impact Did Logistics Contribute to the Plan's Failure? SUBMITTED in PARTIAL FULFILLMENT of the REQUIREMENTS for the DEGREE of MASTER of MILITARY STUDIES." https://apps.dtic.mil/sti/pdfs/ADA491685.pdf.

97 Ibid

98 Ibid

99 "The Guns of August." n.d. Www.digitalhistory.uh.edu. https://www.digitalhistory.uh.edu/disp_textbook.cfm?smtID=2&psid=3474.

100 "The Second Battle of the Marne ." 2016. Info.mysticstamp.com. July 15, 2016. https://info.mysticstamp.com/this-day-in-history-july-15-1918/.

101 Petersen, Craig. 2008. "The Schlieffen War Plan: What Impact Did Logistics Contribute

Germany had expected. In fact, in only 10 days the Russians managed to reach East Prussia, a former German province, forcing a number of German troops to give up western front against the French and Belgians and come back to defend their homeland from Russian invasion.[102] Thus, Germany had arrogantly underestimated the military capabilities of its enemies and overestimated its own, which contributed to its downfall.

The failure of the Schlieffen Plan gave rise to disastrous military, humanitarian, and political repercussions amidst the world war and beyond. In terms of military consequence, after the Allied Powers defeated Germany's offensive at the Battle of Marne in September 1914, a four-year-long trench warfare along the Western Front ensued.[103] The trenches spanned approximately 475 miles from the English Channel all the way to the Swiss Alps.[104] They were generally 6 to 8 feet deep and were extremely constricted in width, for it could only offer no more than two men to pass at the same time.[105] Such a military system was both attritional and catastrophic. It took soldiers years to stand fast in the trenches, to repeat the same actions of attacking, counterattacking, and defending just to procure their nations the minute bits of lands. Yet in the end, neither side gained significant land - the trench wars were atrocious and futile.[106]

In terms of humanitarian impact, the trench wars left soldiers on both sides severely wounded, both physically and mentally. According to the National WWI Museum and Memorial, "after just five months of fighting, the number of dead and wounded exceeded four million men".[107] Apart from the enormous number of casualties, soldiers suffered from severe living conditions and developed serious PTSD even after the war. According to Dunleavy, under the

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to the Plan's Failure? SUBMITTED in PARTIAL FULFILLMENT of the REQUIREMENTS for the DEGREE of MASTER of MILITARY STUDIES." https://apps.dtic.mil/sti/pdfs/ADA491685.pdf.

[102] Onion, Amanda. 2018. "Was Germany Doomed in World War I by the Schlieffen Plan?" HISTORY. September 2018. https://www.history.com/news/was-germany-doomed-in-world-war-i-by-the-schlieffen-plan.

[103] The National WW1 Museum and Memorial. n.d. "Trench Warfare." National WWI Museum and Memorial. https://www.theworldwar.org/learn/about-wwi/trench-warfare.

[104] Ibid

[105] "The Guns of August." n.d. Www.digitalhistory.uh.edu. https://www.digitalhistory.uh.edu/disp_textbook.cfm?smtID=2&psid=3474.

[106] Ducksters. 2019. "World War I for Kids: Trench Warfare." Ducksters.com. 2019. https://www.ducksters.com/history/world_war_i/trench_warfare.php.

[107] The National WW1 Museum and Memorial. n.d. "Trench Warfare." National WWI Museum and Memorial. https://www.theworldwar.org/learn/about-wwi/trench-warfare.

poor trench conditions, "disease and 'shell shock' were rampant".[108] Due to the inevitable mud, dirt, and poisonous air that permeated the trenches, diseases like dysentery, cholera, and typhoid fever were common.[109] Moreover, long term exposure to bombardments had many soldiers develop severe PTSD symptoms that haunted them for the rest of their lives. For instance, by the end of World War I, over 250,000 soldiers were diagnosed with 'shell shock'.[110]

In terms of political ramifications, the military stalemate of the trench wars caused political instability within Europe and paved the path for the ensuing World War II. Since the trench systems rendered the last peace negotiation between the Allied and Central powers impossible, nations all deployed their full force in battle, leaving their own countries more vulnerable to rebellions and civil disobedience. For example, while Britain forces were fighting in the fronts, Irish rebels seized Dublin and rioted for making Ireland independent from British governance.[111] Likewise in Russia, people's discontent over constant warfare and the Czar Nicholas II led to a series of revolutions that eventually replaced the czarist regime with communist governance.[112] Germany, too, had suffered from the deadlock and could no longer afford to sustain the war. It launched submarine warfare against the British to shorten their supply of grain and to damage their economy.[113] This later led the United States to make the political decision of entering the war, which would reshape global alliances and lay the groundwork for future conflicts like World War II.

In conclusion, driven by conflicts over national interests and power struggles, the Schlieffen Plan and the German invasion of Belgium were two pivotal events of World War I. The plan's failure stemmed from the German army's deviation from Schlieffen's original design, logistical and operational deficiencies, and underestimation of the Allies' military capabilities. Ultimately, the two events led to a four-year-long trench warfare between the Allied and Central European countries, and triggered a chain reaction of military escalation, humanitarian crisis, and political instability. These two events changed European history forever and set the stage for future global conflicts like World War II.

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[108] Dunleavy, Brian. 2018. "Life in the Trenches of World War I." History. A&E Television Networks. April 23, 2018. https://www.history.com/news/life-in-the-trenches-of-world-war-i.

[109] Ibid

[110] The National Archives. 2019. "1833 Factory Act." *Nationalarchives.gov.uk* 1 (1). https://www.nationalarchives.gov.uk/education/resources/medicine-on-the-western-front-part-two/shell-shock-cases/

[111] "The Guns of August." n.d. Www.digitalhistory.uh.edu. https://www.digitalhistory.uh.edu/disp_textbook.cfm?smtID=2&psid=3474.

[112] Ibid

[113] Ibid

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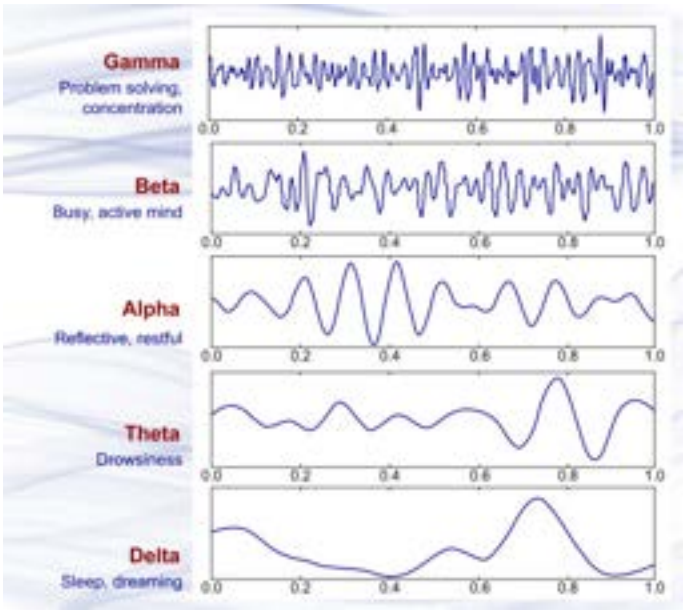
Analyzing the Effects of EEG Brain Wave Signals on Golf Putting Accuracy Using Deep Learning and Neural Networks By Angelina Huang and Cameron Huang

Abstract

Putting, a critical component of golf, relies on the coordination between cognitive processes and motor skills. This study presents an investigation into the impact of electroencephalogram (EEG) brain wave signals such as delta, gamma, theta, alpha, and beta on the accuracy of golf putting, employing deep learning and neural network models. Using a Muse headset, we recorded and processed EEG data during putting to determine the correlation between brain wave patterns and putting precision by measuring and recording the distance from the hole in inches. Our primary metric of evaluation was the distance from the hole, using the root mean square error (RMSE) of the neural network model to assess the predictive accuracy of our models. The findings reveal a statistically significant relationship between EEG patterns and putting accuracy, as evidenced by a low RMSE value of approximately 0.03977. This low RMSE indicates a strong predictive capability of the neural network model in correlating EEG signals with the accuracy of golf putts. In addition, we perform sensitivity analysis to determine the effect of each of the EEG signals in isolation on the distance from the hole. Based on our findings, we determine that EEG signals, including delta, gamma, theta, alpha, and beta waves, have an effect on concentration and focus, which are attributes that improve golf putting accuracy. The results of this research not only advance our understanding of the cognitive processes involved in precision sports but also open avenues for developing training and improvement strategies based on brain wave analysis.

Introduction

This research dives into the application of brain wave EEG (Electroencephalogram) signals in predicting a golfer's putt's distance from the hole. Brain wave signals, essential to this study, are electrical activity patterns in the brain, manifesting in various forms such as delta, theta, alpha, beta, and gamma waves. According to Nayak and Anilkumar (2023), they are commonly categorized based on frequency [7]. Each type of wave signifies different brain states, frequencies, and levels of consciousness. For example, according to NeuroHealth Associates (2022), delta waves (0.5 to 4 hertz (Hz)) relate to deep sleep. According to Kumar and Bhuvaneswari, these waves are found in stages 3 and 4 of sleep (Kumar and Bhuvaneswari, 2012, p. 2530). Beta waves (12 to 30 Hz) are indicative of active, focused thinking and concentration [8]. Alpha waves (8 to 12 Hz) relate to relaxed wakefulness while Gamma waves (25 to 100 Hz) relate to activities, such as problem-solving, and Theta waves relate to light sleeping (NeuroHealth Associates 2022) [8].



An illustration of EEG brain wave signals and their cognitive representation (Priyanka, et al, 2016)

According to Light, Williams, etc. (2010), EEG, a prominent method for recording brain activity, captures these waves via electrodes placed on the scalp. This non-invasive approach provides invaluable real-time insights into brain functions under different conditions, including during sports activities (Light, etc. 2010)[6].

In golf putting, a sport demanding high precision and mental stability, understanding the relationship between brain wave patterns and performance is key. It is hypothesized that certain brain waves, like the focused-alertness beta waves, play a significant role in successful putting. This research aims to identify the specific brain waves that enhance golf putting accuracy and to understand the mental states they represent.

Furthermore, the study examines factors like concentration and focus, vital for peak performance in golf. A vital component of high performance is the ability to block out distraction; one of the ways one achieves this is through selective attention. According to Sörqvist and Marsh (2015), concentration shields us from distraction while reducing our peripheral processing. The ability to maintain a composed yet alert mental state is believed to significantly influence putting accuracy. By analyzing EEG signals during golf putting, the research seeks to uncover the neural underpinnings of high sporting performance, potentially leading to innovative training techniques that improve athletes' concentration and focus, thereby boosting their performance in golf.

Materials and Methodology

Initial Setup – Muse Headset

Figure 1 - Angelina is shown in three photos of her putting with the Muse S Headset. The left-most picture shows the process of visualization before set-up; the middle picture represents how she aligns the ball in between each shot, and the right-most picture presents the front view of her putting with the headset.

The current study utilized the Muse S (Gen 2) Headset. This headset has the capacity to monitor and analyze brain wave frequencies, facilitating the investigation of cognitive states during various activities, such as golf putting, although it is typically used for meditation.

We positioned the Muse Headset on the head, ensuring the band was correctly aligned across the forehead. It was essential to achieve a snug yet comfortable fit to maintain consistent contact with the skin, which is crucial for accurate EEG signal acquisition. Special attention was given to ensure that the electrodes at the back of the band made direct and stable contact with the skin behind the ears. This is a critical step, as these electrodes are responsible for capturing EEG signals.

Before initiating data collection, the Muse Headset was calibrated according to the manufacturer's instructions. This process involved adjusting the headset to the individual's head shape and size to ensure optimal signal quality. The model type Muse S(Gen 2) was used to ensure that the headset remained at a fixed position while the task was performed. The headset was then paired with the Mind Monitor app, a specialized application for visualizing and recording EEG data. This integration allowed for real-time monitoring and recording of brain wave activity during the golf putting tasks and was later converted to a CSV file after completion.

The Muse Headset, once properly set up and calibrated, began recording EEG wave frequencies, including alpha, beta, gamma, delta, and theta waves. I performed 50 putts while wearing the headset to track my EEG signals during my putts. This setup allows me to determine the effects of EEG brainwave signals on golf putting, and aims to identify specific brain wave patterns associated with successful performance.

Data

According to Muse (2023), it contains "7 finely calibrated EEG sensors - 2 on the forehead, 2 behind the ears, and 3 reference sensors - detect and measure the activity of your brain" (Muse 2023). Through Mind Monitor, we measured the TimeStamp, Delta_{TP9, AF7, AF8, TP10}, Alpha_{TP9, AF7, AF8, TP10}, Theta_{TP9, AF7, AF8, TP10}, Beta_{TP9, AF7, AF8, TP10}, and Gamma_{TP9, AF7, AF8, TP10}.

The time stamp gives the exact date, hour, minute, and second the data was recorded. According to Hashemi, Pino, et al., the electrodes TP9 and TP10, indicates that the waves were collected from the temporoparietal location (temporal lobe) while AF7 and AF8 indicated that they were taken from the frontal location behind the ear (Hashemi 2016).

There were 50 data points consisting of 50 putts from a distance of 30 feet. Out of the 50 putts, four putts scored successfully into the hole, as indicated by a 0 datapoint on the unnormalized data.

Training and Test Sets

Since we have 50 points of data, we split our dataset into a training and test set into a 70/30 ratio using the Python library sci-kit, where 70% of the data is used for training the model and 30% of the data is used for testing the model. Our validation set is the same as our test set given the 50 data points and rounds of golf putting that we performed using the Muse headset. Validation sets can often be used to fine-tune neural networks by adjusting hyperparameters given more data points. In our research, we split the dataset into a training and test set for simplicity.

Pre-Processing

In our research, preprocessing of the EEG data was a crucial step, particularly the normalization of the brain wave signals. Normalization is a process that adjusts the data values to fit within a specific range, in our case, between -1 and 1. This standardization is essential for comparing measurements taken under different conditions or at different times, ensuring that the data is consistent and comparable across the entire dataset.

For normalization, we employed the formula:

normalized_data = -1 + 2 * (data – min_val) / (max_val – min_val)

This formula re-scales the original data values, where min_val and max_val represent the minimum and maximum values in the original data set. By transforming the data into this bounded range, we mitigated the potential impact of outliers or extreme values, which can skew our analysis and dataset.

Furthermore, to enhance the reliability of our findings, we implemented a temporal averaging technique. We computed the average of the brain wave signals over the 10-second period preceding each data point. This approach was aimed at reducing random fluctuations in the EEG data, providing a more stable and representative measure of the underlying brain activity prior to the golf putt. Averaging over a 10-second window allowed us to capture more sustained patterns of brain activity that influences the accuracy of the golf putt, rather than transient spikes that might not be relevant to the broader context of our study.

Experimentation – Neural Networks

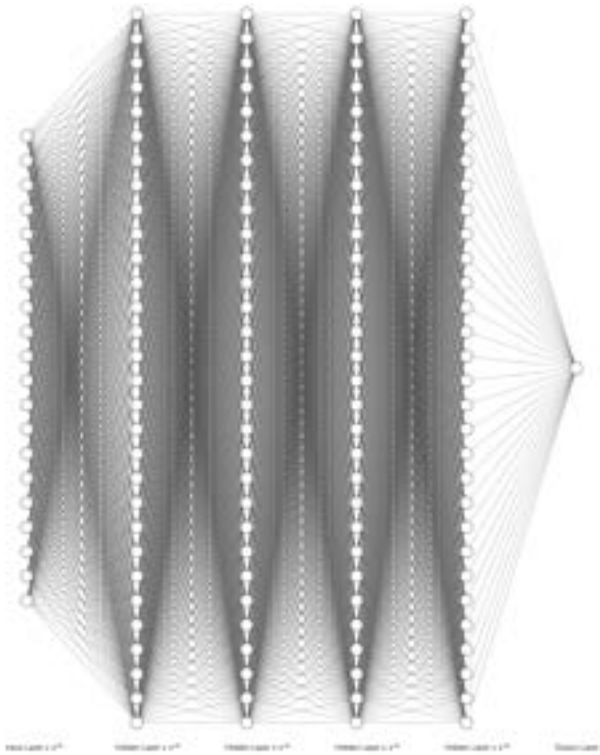
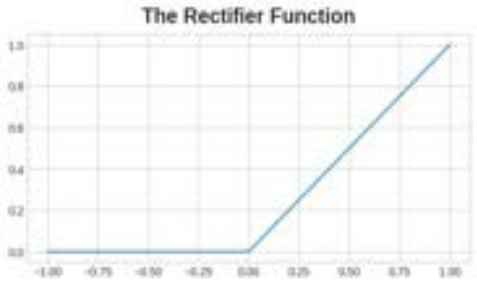


Figure 2 – This model represents the neural network. The leftmost layer is the input layer where 20 neurons, which reflect the 20 independent variables of five categories of brain wave signals: Delta_{TP9, AF7, AF8, TP10}, Alpha_{TP9, AF7, AF8, TP10}, Theta_{TP9, AF7, AF8, TP10}, Beta_{TP9, AF7, AF8, TP10}, and Gamma_{TP9, AF7, AF8, TP10}. The middle four layers consist of the hidden layers with 500 nodes in each hidden layer. The rightmost layer is the output layer, consisting of a single neuron. It is

important to note that the four hidden layers in the neural network above represent 500 nodes.

The neural network, beginning with its 20 inputs representing diverse brain wave data of delta, gamma, theta, alpha, and beta for each of the TP9, TP10, AF7, and AF8 electrodes, processes this information through its four hidden layers. Each hidden layer, consisting of 500 nodes, refines and abstracts the data, learning complex patterns within the brain wave signals. We determined 500 nodes and 4 hidden layers after experimenting with and fine-tuning our model to achieve a low MSE in our training set.

The activation function ReLU (rectified linear unit) at each node was used to account for the non-linearity of the dataset in the neural network model and account for complex patterns in the data. Given EEG brain wave signals are non-linear, the activation function ReLU is an appropriate choice for our neural network. This non-linearity is crucial for deep learning models that need to make sense of complicated, non-linear real-world data, especially the spikes in brain waves.



During training, this process is repeated across multiple iterations or epochs - in this case, four epochs. An epoch represents one complete pass of the entire dataset through the neural network. This means that the entire set of 20 inputs is processed through the network four times, allowing the model to iteratively adjust and optimize its weights and biases for better accuracy and performance.

The batch size of 4 plays a crucial role in how the data is presented to the network during each epoch. Instead of processing all data points at once, the network handles the data in smaller batches of 4. This means that for each epoch, the entire dataset is divided into smaller subsets, each containing 4 data points. The network updates its internal parameters after processing each batch. This approach can lead to more efficient and stable training of the neural network.

Finally, after processing through the epochs and batches, the network outputs a single variable: the predicted distance.

Deep learning models are trained by minimizing the loss function and updating the weights to achieve greater accuracy as it is fed more data. In order to minimize the cost function of our neural network, we use Stochastic Gradient Descent (SGD). This process aims to reduce

the loss by finding a point where the loss is at a local minimum, which might be a saddle point or a global minimum. SGD operates by computing partial derivatives to determine the gradients of the weights. These gradients indicate the direction and magnitude of the weight adjustments needed to minimize the loss.

Stochastic Gradient Descent:
The cost function is represented by J(x):

$$J(x) = \frac{1}{n}\sum_{n=1}^{m}(y_i - w_0 - w_1x_1 - w_2x_2 - \ldots - w_nx_n)^2$$

$$\min J(x) = \frac{1}{n}\sum_{n=1}^{m}(y_i - w_0 - w_1x_1 - w_2x_2 - \ldots - w_nx_n)^2$$

Updating weights in Backpropagation:

$$w_i := w_i - \alpha \cdot \frac{\partial}{\partial w_i} J(w_0, w_1, \ldots w_n)$$

$$w_i := w_i - \alpha \cdot \frac{\partial}{\partial w_i} \cdot \frac{1}{n}\sum_{n=1}^{m}(y_i - w_0 - w_1x_1 - w_2x_2 - \ldots - w_nx_n)^2$$

Through backpropagation, the weights are continuously updated, which minimizes the loss function to improve the model. This updating process continues until the algorithm reaches a point where further adjustments do not significantly reduce the loss function. The neural network executes feedforward propagation to make predictions, calculates the loss for these predictions, and then uses backpropagation to adjust the weights accordingly. This cycle of forward and backward propagation, with the SGD, enables the neural network to progressively reduce its loss and improve its performance.

Sensitivity Analysis

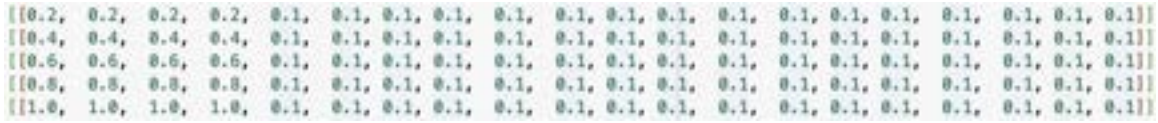
In addition to analyzing the mean squared error (MSE) to test the accuracy of our model, we also perform sensitivity analysis to determine the effect of each of the brain wave signals delta, theta, alpha, beta, and gamma on different regions of the brain on golf putting accuracy.

To perform sensitivity analysis, we create a 5x20 matrix with initial values of 0.1. We assign an initial value of 0.1 to each of the brain wave signals to reflect a low level of brain waves without any spikes.

Next, we increase the values of the first four columns or features in our data set, which represent Delta_TP9, Delta_AF7, Delta_AF8, and Delta_TP10, by increments of 0.2 to

determine the effect of an increase in delta brain wave signals on the distance of the golf ball away from the hole.

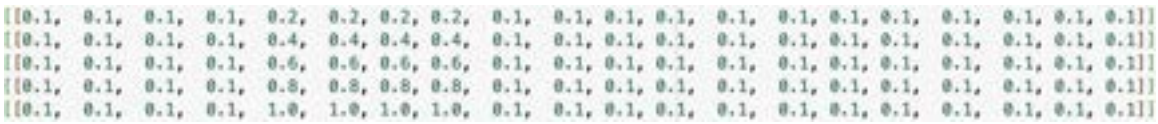
The following matrix illustrates this:



Sensitivity analysis by increasing delta signals Delta_TP9, Delta_AF7, Delta_AF8, and Delta_TP10 by increments of 0.2

To test the other brain waves, we increase the values of the first four columns or features in our data set, which represent Theta_TP9, Theta_AF7, Theta_AF8, and Theta_TP10, by increments of 0.2 to determine the effect of an increase in theta brain wave signals on the distance of the golf ball away from the hole.

The following matrix illustrates this pattern:



Sensitivity analysis by increasing theta signals Theta_TP9, Theta_AF7, Theta_AF8, and Theta_TP10 by increments of 0.2

We continue this pattern and eventually conduct sensitivity analysis for the following:

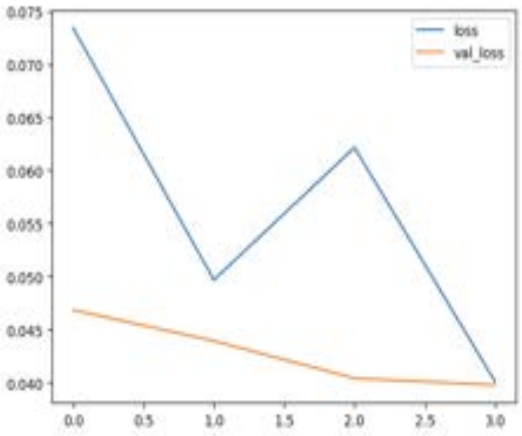
- **Delta:** Delta_TP9, Delta_AF7, Delta_AF8, and Delta_TP10
- **Theta:** Theta_TP9, Theta_AF7, Theta_AF8, and Theta_TP10
- **Alpha:** Alpha_TP9, Alpha_AF7, Alpha_AF8, and Alpha_TP10
- **Beta:** Beta_TP9, Beta_AF7, Beta_AF8, Beta_TP10
- **Gamma:** Gamma_TP9, Gamma_AF7, Gamma_AF8, Gamma_TP10

By performing the above sensitivity analysis for the delta, theta, alpha, beta, and gamma signals in our neural network, we can determine the effects of each of these signals on golf putting accuracy measured by the distance from the hole. Since neural networks are considered a "black box," this sensitivity analysis enables us to determine the effects of each of these EEG signals in isolation.

Results

Our results are two fold: 1) we measure the accuracy of our model based on the distance from the hole through golf putting using the mean squared error (MSE) based on our test set and 2) we determine the effects of each of the EEG signals on golf distance using sensitivity analysis.

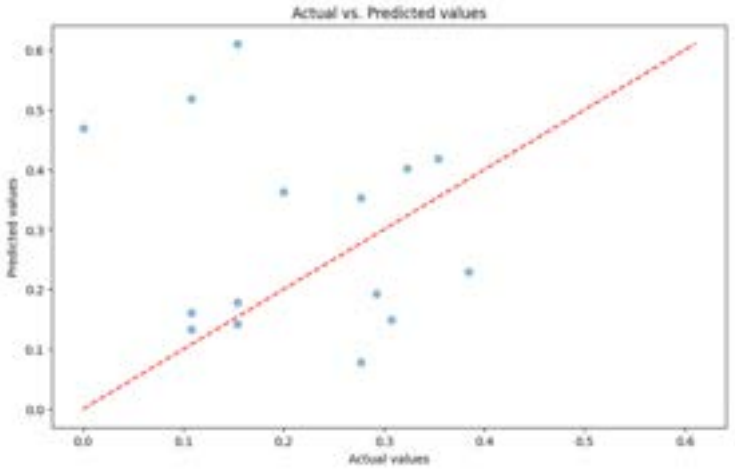
Mean Squared Error (MSE):



In our analysis of the neural network model tailored for predicting 'Distance', a Mean Squared Error (MSE) of approximately 0.03977 based on our test set was achieved. This metric indicates a relatively low level of error in the predictions, and you can see the training set (loss) and test set (val_loss) converge. The process of fine-tuning the model involved adjustments in the network's architecture, including varying the number of nodes and hidden layers.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2$$

These modifications played a crucial role in optimizing the model's performance, as evidenced by the observed fluctuations in MSE values. The training process utilized a small batch size of 4, given the dataset's limited size of only 50 data points. This approach, combined with a total of 4 epochs, allowed the model to learn effectively from each subset of the data across multiple iterations.



The MSE is calculated based on actual vs. predicted values

Sensitivity Analysis Results

Based on our sensitivity analysis, we determined that the increase in theta waves leads to a decrease the distance from the putt. In addition, the increase in beta waves leads to a decrease in the distance from the putt, but past the 0.6 increment, the distance from the hole increased. Gamma waves remained stagnant while the increase in Delta and Alpha waves actually led to an increase in distance from the hole. Further research needs to be conducted in this area to reach conclusive results, including gathering more data and fine-tuning the models with different nodes, layers, epochs.

Normalized Distances from the Hole based on the following EEG signals:

Increment	Delta	Theta	Alpha	Beta	Gamma
0.2	0.17579828	0.1824621	0.190744	0.17267884	0.17824286
0.4	0.18197533	0.1782736	0.2173582	0.163052	0.17844127
0.6	0.18864322	0.17229182	0.24720079	0.1542415	0.17806713
0.8	0.2082343	0.16433553	0.2754131	0.15679371	0.17853062
1.0	0.22911723	0.15187652	0.30386847	0.15946811	0.17935993

As illustrated in the table above, the distance from the golf ball to the hole decreased as theta and beta waves increased, which means greater accuracy in putting. Higher ranges of theta waves can lead to inward-focused problem solving particularly in deep meditative states. This is especially applicable during golf putting where precision and creativity in assessing wind conditions are required. Each time, the golfer resets for each putt, resulting in new environmental interactions (Dias etc. 2021). Thus, the creativity needed to adapt to new situations and the visualization for the ball's path to the hole may affect golf putting accuracy. Moderate amounts of beta waves can lead to increased concentration, which improves golf putting accuracy. However, since the distance from the hole grew further from increments 0.6 to 1.0, we can suspect that it approaches the mid-range / high beta waves, which may produce stress or anxiety, both a negative stressor to performance (Priyanka etc. 2016).

Discussion and Conclusion

In analyzing the relationship between brain wave signals and golf putting accuracy, our study found that alpha, delta, theta, beta, and gamma waves at the electrode locations TP9, AF7, AF8, and TP10 can be used to predict golf putting accuracy.

Alpha waves are often linked to a state of relaxed alertness, and Beta waves are associated with active concentration. This suggests that a golfer's ability to remain calm yet focused is crucial for precision in putting.

Delta waves, which predominantly occur during deep sleep (stages 3 and 4 of non-REM sleep), was another factor in our deep learning model. While their direct influence on an awake activity like golf putting is unclear, this finding could indicate the indirect benefits of quality sleep, which involves delta wave activity, on cognitive functions relevant to golf, such as focus and coordination.

Theta waves are associated with light sleep, which was another input into our model. This might reflect the benefits of a relaxed, yet attentive state, which could facilitate creative visualization strategies in golf putting. However, further research must be conducted to test its significance.

Finally, gamma waves, associated with heightened perception and focus, can contribute to improved attention to detail and concentration during golf putting. Their role in integrating information across different brain regions may also aid in coordinating physical movement with strategic decision-making in golf.

Future research could benefit from performing more rounds of golf putting using the Muse Headset given 50 datapoints may not have captured the entire picture. We can also experiment with recording the EEG signals at 1-2 second increments in the 10-second duration of the putt instead of taking the average to determine whether it yields any meaningful insights or results. With deep learning, more data will allow us to greater train and fine-tune our model for improved accuracy and efficiency.

Further areas of research for consideration may take a more holistic approach, considering variables like emotional states, weather conditions, sleep quality, and nutrition, all of which could have substantial impacts on a golfer's performance. The complexity of the task and the number of factors influencing performance indicate that brain wave signals alone might not capture the full picture.

By integrating these factors, we could develop a more comprehensive model that not only enhances our understanding of the cognitive processes involved in golf but also improve training and preparation regimen for optimal athletic performance.

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Utilizing a Neural Network to Predict "Value" of Various Soccer Players By Peter How

Abstract

I used machine learning concepts and applied them to a data set of soccer players to create a model that predicts their "value." The data contains 2611 soccer players. An open-source library, Keras, which is in TensorFlow, is used in this analysis. I used Neural Networks. The dataset is divided into a training dataset (75%) and a validation dataset (25%). The model is trained on the training set. The validation set shows the model generalizes well to new examples.

Introduction

Machine learning is a branch of artificial intelligence (AI) and computer science which focuses on the use of data and algorithms to imitate the way that humans learn, gradually improving its accuracy.. Over the last couple of decades, the technological advances in storage and processing power have enabled some innovative products based on machine learning, such as Netflix's recommendation engine and self-driving cars (IBM, 2023). Machine learning utilizes algorithms to find patterns in data sets, and create a model that makes predictions.

name	full_name	age	height	nationality	place_of_birth	price	max_price	position	shirt_nr	foot	club	contract_expires	joined_club	player_agent	outfitter	league
Ederson		29	1.88	Brazil Portugal	Osasco (SP)	45	70	Goalkeeper	31	left	Man City	2026-06-30	2017-07-01	Gestifute	Puma	EPL

Data Preprocessing

I got the data set originally had 17 columns and 2611 rows. There were several columns that had no effect on the label so I dropped them. Those rows were: "place_of_birth", "shirt_nr", "contract_expires", "joined_club", "player_agent", "full_name", "name", and "nationality". I also dropped about 70 rows because of a lack of data in some columns.

When preprocessing your data it is important to make your turn your categorical features numerical. This process is known as one hot encoding. In order to do this you assign on category 1 and the other zero. In the case of the row "foot", I turned "left" into "0" and "right" into "1".

I performed a similar process for the column "outfitter". The column "outfitter" had far too many unique features to perform one hot encoding, so I changed the row to "has and outfitter". I replaced "1" with any value in the column, and "0" with "none" or "NaN".

When a categorical variable has more than two possible categories: For each possible category, we create a new variable. Given an example, the variable that corresponds to the category of the example takes the value 1. The rest of the variables take the value 0. These numerical variables replace the original categorical variable. I applied this process for the row: "position", as shown in table 2.

```
df['Goalkeeper'] = (df['position'] == 'Goalkeeper')*1
df['Centre_Back'] = (df['position'] == 'Defender - Centre-Back')*1
df['Left_Back'] = (df['position'] == 'Defender - Left-Back')*1
df['Right_Back'] = (df['position'] == 'Defender - Right-Back')*1
df['Defensive_Midfield'] = (df['position'] == 'midfield - Defensive Midfield')*1
df['Central_Midfield'] = (df['position'] == 'midfield - Central Midfield')*1
df['Attacking_Midfield'] = (df['position'] == 'midfield - Attacking Midfield')*1
df['Left_Winger'] = (df['position'] == 'Attack - Left Winger')*1
df['Right_Winger'] = (df['position'] == 'Attack - Right Winger')*1
df['Centre_Forward'] = (df['position'] == 'Attack - Centre-Forward')*1
df['Second_Striker'] = (df['position'] == 'Attack - Second Striker')*1
df['Left_Midfield'] = (df['position'] == 'midfield - Left Midfield')*1
df['Right_Midfield'] = (df['position'] == 'midfield - Right Midfield')*1
df['Midfield'] = (df['position'] == 'midfield')*1
df = df.drop(columns=['position'])
```

I used the same process on the column “league”, by creating a column for each unique value “league”. Finally after processing the data I was left with a data frame with 27 columns and 2561 rows.

	age	height	price	max_price	foot	outfitter	Goalkeeper	Centre_Back	Left_Back	Right_Back	...	Second_Striker	Left_Midfield	Right_Midfield	Midfield	EPL	Bundesliga	SerieA	LaLiga	Ligue2	Other_League
0	29	1.88	45	70	0	1	1	0	0	0	...	0	0	0	0	1	0	0	0	0	0
1	30	1.85	6	6	1	0	1	0	0	0	...	0	0	0	0	1	0	0	0	0	0
2	37	1.88	0.25	6	1	1	1	0	0	0	...	0	0	0	0	1	0	0	0	0	0
3	26	1.87	75	75	1	1	0	1	0	0	...	0	0	0	0	1	0	0	0	0	0
4	28	1.8	35	40	0	1	0	1	0	0	...	0	0	0	0	1	0	0	0	0	0

Training and Validation Set

The set of examples are randomly split into two sets: training and validation. The training set contains 75% of the examples, and the validation set contains 25% of the examples. The model will be trained on the training set. The validation set will be used only to evaluate the performance of the models.

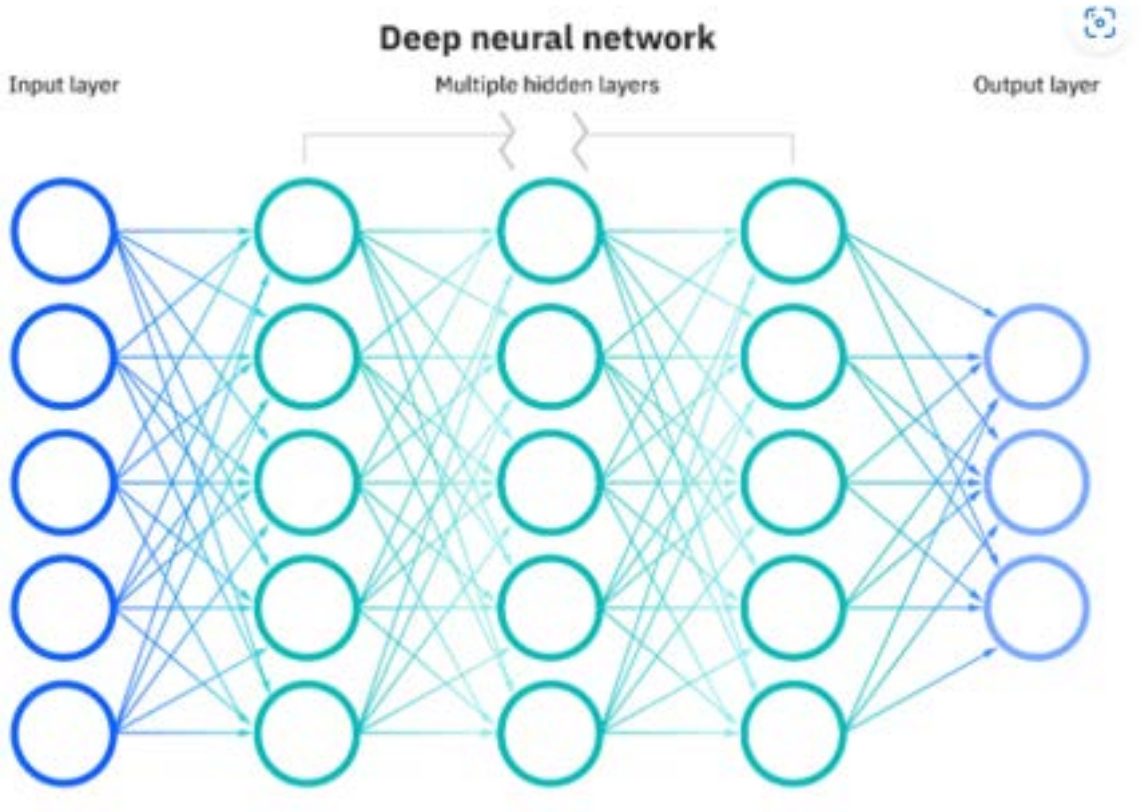
Regression Problem

The problem in this analysis can be classified as a regression problem. First of all, this analysis utilizes supervised learning. Supervised learning is a machine learning approach that’s defined by its utilization of labeled datasets. These datasets are designed to train or “supervise” algorithms into classifying data accurately. Using labeled inputs and outputs, the model can measure its accuracy and learn over time (Delua, 2021). There are two main subcategories of supervised learning: regression and classification. We will be going over regression. Regression predictive modeling is the task of approximating a mapping function (f) from input variables (X)

to a continuous output variable (y). A continuous output variable is a real-value, such as an integer or floating point value. These are often quantities, such as amounts and sizes. For example, a house may be predicted to sell for a specific dollar value or in this case the value of a soccer player (Brownlee, 2017).

Neural Network

Neural networks are a subset of machine learning. Their name and structure are inspired by the human brain, mimicking the way that neurons in the brain signal to one another. Neural Networks work for both classification and regression problems. As seen in the model, neural networks (ANNs) are composed of a node layer, an input layer, one or more hidden layers, and an output layer. Each node connects to another and has an associated weight and threshold. If the output of any individual node is above the specified threshold value, that node is activated, sending data to the next layer of the network. Otherwise, no data is passed along to the next layer of the network (IBM, 2021).



Measuring the Quality of The Model

For regression problems a common metric to determine the quality or effectiveness of the model is mean square error. Mean Squared Error (MSE) of an estimator (of a procedure for estimating an unobserved quantity) measures the average of the squares of the errors, or the average squared difference between the estimated values and the actual value. MSE is a risk function, corresponding to the expected value of the squared error loss. MSE is almost always

strictly positive (and not zero) because of randomness or because the estimator does not account for information that could produce a more accurate estimate. MSE is always non-negative and the closer to zero the better the model. MSE is calculated as in the figure (Hiregoudar, 2020).

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2.$$

Mean Squared Error (MSE) Formula

Applications to the Prediction of "value" for Soccer Players

I used a neural network approach as described previously, to analyze the data set for soccer players in the top five leagues in Europe in order to train a model to predict their "value". The figure below displays the code for this analysis.

```
model = 0
model = Sequential()
model.add(Dense(1))
model.add(Dense(4, activation='relu'))
model.add(Dense(2, activation='relu'))
model.compile(loss='MSE')
model.fit(X_train_scaled,Y_train,epochs= 800,  verbose=0, validation_data = (X_val_scaled,Y_val))
J_list = model.history.history['loss']
plt.plot(J_list)
```

The mean squared error on the training set is 59.049915. After the model is trained with the training set, the model is applied to the validation set to validate the model. The mean squared error on the validation set is 67.128700, which is about the same as that on the training set.

I found that epochs = 800 resulted in the best results as anything higher resulted in overfitting. Overfitting refers to a modeling error that occurs when a function corresponds too closely to an individual data set. Overfitting may fail to fit additional data, and this may affect the accuracy of predicting future observations. Overfitting can be identified by checking validation metrics such as accuracy and loss. If the model performs about the same on the validation dataset as that on the training dataset, overfitting usually is not an issue in the model.

Conclusion

A model based on machine learning concepts and libraries has been developed to predict a soccer player's value. The tools and the model "Sequential" in the two machine learning libraries, TensorFlow and Keras, were used to build the model. The model is trained and validated with a dataset of soccer players from various leagues in europe. The dataset is divided into training dataset (75%) and validation dataset (25%). The training dataset is used to train the model. The trained model is then applied to the validation dataset to prevent overfitting. The

model works well on both trained dataset and validation dataset. The model did well in both training dataset and validation dataset with a similar mean square error of 59.049915 and 67.128700 when epoch equals 800. The dataset does not show any symptom for overfitting. As a result, the model should do well when predicting the “value” of a new soccer player.

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The Impact of Air Quality on Students Academics, Motivation and Mental Health
By Tithi Raval

Abstract

Poor air quality is a serious global issue, affecting all of the human population. The sources and mechanisms by which pollutants contribute to poor air quality are well documented, as are the associated deleterious health impacts. This paper focuses on a public health aspect of air quality science, asking how air quality affects students' academics, motivation, and mental health – as it will review current learnings within these specific fields as well as an investigated and analyzed experiment to expand on these findings. Many sources and studies concluded that poor air quality is associated with lower academic success, and degrades mental health in students and adolescents. This paper considers the academic performance, mental health, and motivation of students who may be exposed to poor air quality. These areas are evaluated using a self-assessment questionnaire. The questionnaire is directed toward teenage students from various environments and geographical locations, to assess if outdoor air quality affects high school-age students' academics, motivation, and mental health. The main objective of this study was to answer the following question: How does outdoor air quality affect students' academics, motivation, and mental health? A hypothesis suggests that with better air quality, students would be more productive and motivated to score higher on exams and also show better mental health quality. The results of the experiment were documented and statistically analyzed to draw conclusions based on the collected dataset of responses from the questionnaire. An interpretation of the results followed to find correlations between air quality and students' academics and their mental well-being. The study results indicated that in areas of poor air quality, students' were relatively unproductive, demotivated, and experienced weaker mental health in terms of restlessness, stress, anxiety, and depression.

Key Words: academic performance, air quality, Air Quality Index (AQI), particulate matter, PM 2.5, pollutants

Introduction

Air pollution poses significant risks to various demographics within society, as specific groups of people, such as the elderly, children, and those with chronic illnesses are more susceptible to the effects of pollution. More than 100 million people live in areas with air pollution exceeding the health-based air quality standards in the United States (Nolte). According to environmentalist Richard Fuller, even though UN agencies, groups, and national governments are taking steps to solve this issue, little progress has been shown, especially in low-income countries with high levels of pollution (Fuller).

Air pollution is derived from both natural sources, such as wildfires and volcanoes, and human-generated sources, like smoke, ash, and gasses derived from the combustion of fossil fuels. ("Air Pollution and Your Health"). The United States Environmental Protection Agency (EPA) emphasizes the six common air pollutants: ground-level ozone, particulate matter, carbon

monoxide, lead, sulfur dioxide, and nitrogen dioxide (“Criteria Air Pollutants”). These air pollutants are proven to deteriorate respiratory health and are associated with oxidative stress and inflammation in human cells, leading to chronic diseases and cancer. Health concerns include cancer, cardiovascular and respiratory diseases, diabetes, obesity, and reproductive, neurological, and immune system disorders (“Air Pollution and Your Health”).

The vast majority of the published literature on air pollution has focused on covering the effects of poor air quality on students' academic performance and their mental health. For example, after conducting a survey-based study, researchers from the National Library of Medicine reported that ambient air pollution is linked with reduced Math and English Language Arts test scores among students (Lu, et al.). This study expands on and emphasizes how exposure to 12-month ambient air pollution levels is associated with neuroinflammation, neurodegeneration, and cognitive decline in terms of the students’ attentiveness, and memory, especially in developing and growing children. Black carbon is a material released from gasses and burning fossil fuels, which makes up a large part of the particulate matter air pollutant (“Black Carbon Research and Future Strategies”). The American Journal of Epidemiology discusses a study and concludes that kids experiencing certain levels of black carbon scored worse on memory and IQ assessments (Weir).

Additionally, a Cambridge study exploring the effects of air quality on mental health focuses on major effects on adults such as depression, anxiety, personality disorders, and schizophrenia caused by exposure to outdoor air pollutants (Kamaldeep, et al.). The paper also included that in a study of 2063 adolescents, psychotic experiences were common for those exposed to the highest levels of pollutants such as PM2.5 and nitrogen dioxide. Among adults, there was an evident association between long-term exposure to PM2.5 and depression, bipolar disorder, or suicide.

Furthermore, the significance of this topic caught the attention of a group of Japanese researchers, who focused on studying the effect of air pollution on individual students' motivation and productivity (Kameda, et al.). Their research incorporated a controlled experiment to gather and analyze relevant data regarding each student's motivation levels in a classroom with correlation to the air in their environment. At the end of their study, researchers concluded that in an environment with poor air, students' motivation and learning desires decreased widely as well as their performance. The motivation for learning in a ventilated environment was higher by 3.7 - 11.7 percent than in a classroom with poor air quality.

Existing literature suggests that there is a strong correlation between air quality, student mental health, and academic performance. However, there is a limited amount of research that investigates the relationship between outdoor air quality and its effects on students' motivation and each individual’s desire for productivity. This study aims to address this gap. By measuring air quality from public air monitors and simultaneously asking middle and high school-aged students throughout the United States about their academics, motivation, and mental health, this study hoped to test the hypothesis: with better air quality, students are more productive and motivated and have better mental health.

The primary metric of air quality used in this study was particulate matter, specifically PM2.5 – small particles in air that are 2.5 micrometers in diameter or less. PM 2.5 is a heterogeneous mixture that can include organic chemicals like sulfates, nitrates, or carbon; dust; soot; and metals. These particles can come from automobile exhaust, factory processes, wood burning, and other activities (Manisalidis, et al). Unlike other air pollutants like ozone, particulate matter can be either directly emitted or can form within the atmosphere as a result of chemical reactions between pollutants. PM2.5 is easily affected by weather conditions like temperature, humidity, wind speed, and rainfall, with direct relation to climate change (Nolte). According to the EPA, PM 2.5 is used as a crucial indicator of air quality because smaller particles can enter the lungs and the bloodstream ("How Does PM Affect Human Health"). Fine particle pollution has been shown to cause many serious health effects, including heart and lung disease. Exposure to PM2.5 contributes to thousands of deaths every year. Children, the elderly, and people suffering from heart or lung disease, asthma, or chronic illness are most sensitive to the effects of PM2.5 exposure ("Inhalable Particulate Matter and Health").

This paper consists of a synthesis of prior research and an original experiment to investigate the major effects of poor air quality on a few aspects of students' lives such as their day-to-day academic successes, mental health, as well as their daily drive for productivity.

Methodology

This study began with researching and gaining background content about some ways of how air quality affects aspects of students' lives. Research material was gathered from Google Scholar articles and government organization websites, utilizing keywords such as 'academic performance,' 'air quality,' 'particulate matter,' 'pollutants,' and 'PM2.5.'

The research study was conducted through an anonymized online Google form questionnaire to investigate the impact of poor air quality on students' academics, motivation, and mental health. The survey targeted high school students aged 12 to 20, encompassing diverse gender and age groups. The survey was sent to about 30 students around the United States to ensure variated and comprehensive data. The questionnaire comprised three sections: consent confirmation, participant background, and self-analysis. The consent section required participants to read an overview of the study and provide a mandatory signature to confirm their participation in the experiment. Following this, students supplied some background details such as age and gender before proceeding to the self-analysis section. Through the self-analysis, participants were asked to analyze their academics during a specific day, involving their motivation, productivity, and school successes in exams and assessments. They were asked questions about how academically stimulated they were during the day and if the air environment affected their motivation. Additionally, the participants were asked to reflect on their mental health based on aspects such as restlessness, stress, anxiousness, and depression. A copy of the consent form and Google form questionnaire can be found in the supplemental information section. An Internal review board approved of the study: consent and participant identity were adhered to throughout this study.

Air Quality Index (AQI) is divided into six categories corresponding to different levels of health effects (“Air Quality Index”). These AQI index ranges were used during the analysis of data for the study.

AQI	Level of Concern
301 and higher	Hazardous
201 - 300	Very Unhealthy
151 - 200	Unhealthy
101 - 150	Unhealthy for Sensitive people
51 - 100	Moderate
0 - 50	Good

Air Quality Index (AQI) values from PurpleAir Monitors were utilized to correlate with participants' responses based on the survey date. PurpleAir sensors use reflections to count particles considering their sizes and conclude the types of particles present. PurpleAir particulate matter (PM) sensors are used in many countries by a variety of individuals and organizations for the continuous monitoring of ambient air pollutant conditions. The PurpleAir website displays a real-time map of the air quality all over the world. The map has capabilities to display the variations of air pollutants like particle matter (PM2.5, PM10), and ozone in the air (“Real-Time Air Quality Map”). For this specific study, the PurpleAir PM2.5 AQI values were used because the large number of sensors around the world increased the chances of an available sensor located near each participant. Based on the student’s location, a sensor was selected within the city and its data was downloaded as a CSV file. The file consisted of AQI values for the past 3 months at six-hour intervals. The average of four data points was considered, representing the AQI throughout the specific day that each participant filled out the questionnaire.

Upon data collection, responses were organized on a Google Sheet to establish correlations between participants' inputs and variations in AQI levels. Motivation, mental health, and productivity variables were segregated into different sub-sheets alongside corresponding AQI values. The independent variable was Air Quality, AQI, whereas the dependent variable was the students’ academic performance, motivation level, and mental health. Meticulous outreach was conducted over four weeks, involving contacts around the United States and email communication with schools.

The gathered data was then processed to generate graphs using Python libraries: Matplotlib, Pandas, and NumPy. Visualizations, including bar, pie, and line graphs, facilitated the formulation of conclusive observations regarding the study's objectives. The trends were then

analyzed using statistical tests, like the t-test. The utilization of these advanced statistical tools enhanced the robustness and reliability of the study's findings.

Results and Discussion

Table 1
Demographics of the Study Population

Age (in years)			
	Female (N=15) (57.7%) [a]	Male (N=11) (42.3%)	Total (N=26)
Below 12	2	2	4
12 - 14	6	3	9
15 - 17	6	2	8
18 - 20	0	1	1
Above 20	1	3	4
Location in United States [b]			
	Female (N=15)	Male (N=9)	Total (N=24)
Western states	9	5	14
Central and Midwest states	3	3	6
Eastern states	3	1	4

Note. From the questionnaire, twenty-six students completed the survey over a span of four weeks, from November 27 to December 25, 2023. Participant background statistics are presented in Table 1. The data showed that two students didn’t include their location, therefore they were disregarded as a part of the study. Only 24 participant responses were used in the parts of the studies analysis using locations. Analysis of results emphasized the potential effects that short-term exposure to particulate matter has on students' academic performance, motivation and mental health separately.

[a] 57.7% were female, while 42.3% of the participants were males: 15 females and 11 males. The majority of the participants were in the age range 12 to 17, whereas the least number of participants were between ages 18 to 20. The mean age was 15 years old. [b] Additionally, 14 students were from Western states, 6 from Central or Midwest, and 4 participated from Eastern states.

Figure 1 illustrates the correlation between participant's average air quality and their indicated productivity levels on a 1 to 5 scale (1: least productive; 5: most productive). The average air quality for participants who responded as feeling the least productive (Level 1) during the day was 104, while the average air quality for participants who responded as feeling the most productive (Level 5) was 52. Two participants responded feeling Level 1 productivity, one responded with Level 2 productivity, Six responded, feeling Level 3 productivity, eleven participants responded, feeling Level 4 productivity, and four participants responded as feeling Level 5 productivity during the day of survey completion.

This analysis aimed to understand the correlation between the productivity levels and the outdoor Air Quality Index (AQI) measures. Data was divided into two groups: Group One (Levels 1-3) for lower productivity and Group Two (Levels 4-5) for higher productivity. Group One had 9 students with a mean AQI of 81.45, while Group Two had 15 students with a mean AQI of 60.0. An independent sample t-test (t-statistic = 2.2, df = 22, p = 0.04) revealed a significant difference between the groups, indicating that students with lower productivity levels had a higher mean AQI than those with higher productivity.

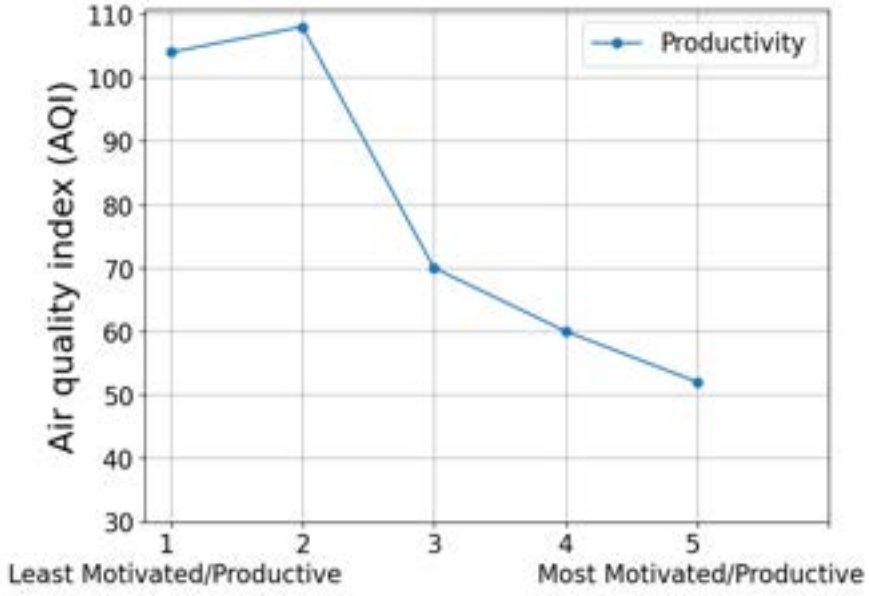

Figure 1: Productivity Levels vs. AQI

Figure 2 shows the correlation between the average air quality during two days for each participant indicating a specific level of motivation on a 1-5 scale (1: least motivated; 5: most

motivated. The questionnaire asked for participants' ratings of motivation on the day of filling out the survey and the day prior, to prove or disprove a potential correlation. The average air quality for participants feeling least motivated (1) was 97, whereas the average air quality for participants feeling the most motivated (5) on the day they filled out the questionnaire was 53. The average air quality, the day before filling out the survey, for participants feeling least motivated (1) was 98, but 37 for most motivated (5) students. Figure 2 shows a negative correlation between Motivation and AQI levels, for both days. It can be concluded that with poor air quality, students feel less motivation, but with healthy air quality, students are more motivated throughout the day.

The main purpose of this survey was to analyze the relationship between students' motivation and the AQI levels. Data from the questionnaire response of rating motivation on a 1-5 scale was grouped into two categories to conduct a t-test. Group 1 consisted of AQI values corresponding to participants responding with levels 1 - 3 motivation. Group 2 consisted of the values corresponding to participants with motivation levels, 4 - 5. Group 1 consisted of 11 participants, with a mean AQI of 77.7. Group 2 consisted of 13 students and the mean AQI was 61.0. An independent sample t-test was conducted, comparing the means of both groups. The t-statistic for the test was 2.2, df = 22, with a p-value of 0.03 ($p < 0.05$). This test suggested a significant relationship between the mean values of both Groups. Group 1 (lower motivation levels) had a larger mean value of AQI measures than Group 2.

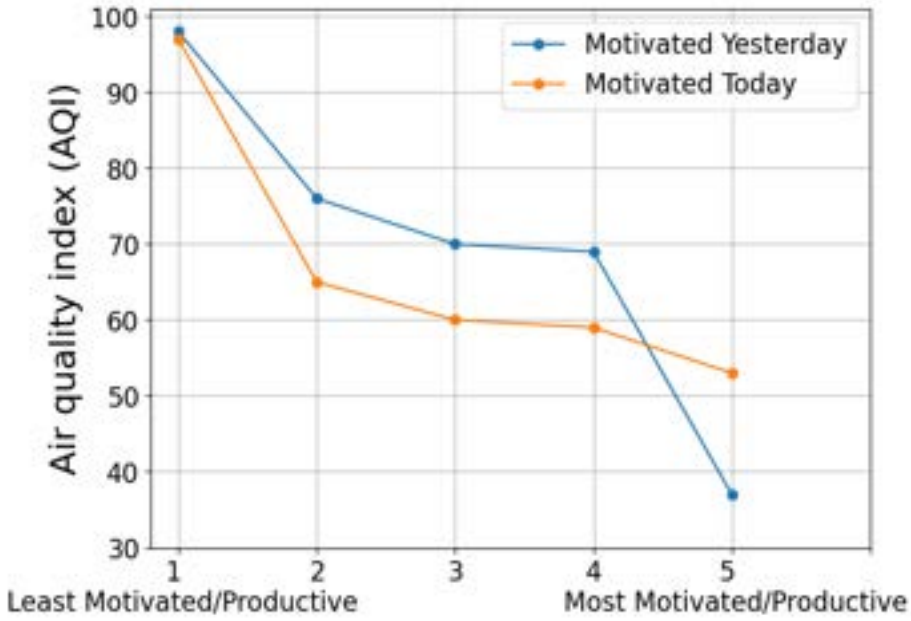

Figure 2: Motivation Levels vs. AQI

Figure 3 presents students' self-reflection regarding their mental health during the day, corresponding to the average AQI. These self-reflection questions were required to find a correlation between mental health and AQI. A total of seven participants from the survey

responded on a day with less than 50 AQI, 14 were located in an area with AQI levels between 51 and 100, while 3 experienced above 100 AQI. All of the students living in an area with healthy AQI levels below 50 responded with ‘never’ or ‘sometimes’ feeling restless and depressed. Six out of seven students who had AQI below 50 responded with ‘never’ or ‘sometimes’ feeling stressed and anxious. All participants living with AQI levels above 100 responded with ‘always’ for feeling anxious and stressed. These results indicate that students exposed to lower AQI levels (less than 50, or 51 - 100) during the day are more likely to maintain better mental health quality in terms of feeling restless, stressed, anxious, and depressed. The participants who were experiencing higher AQI (above 100), tended to show lower mental health quality.

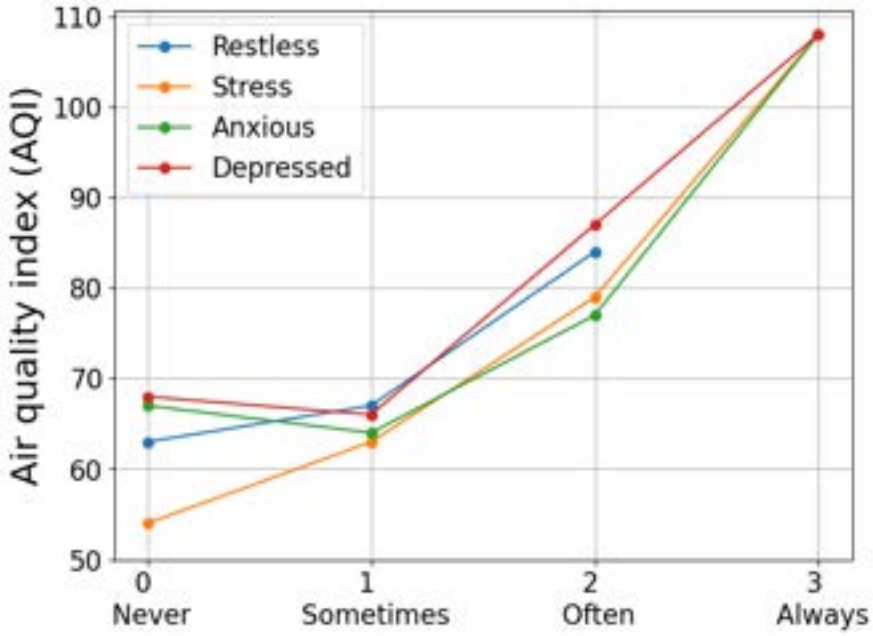

Figure 3: Participants Mental Health Ratings

These survey results revealed a notable trend that older participants are more aware of the air environment. When participants were asked if they “notice when air quality is poor”, 20 students responded “Yes”, 3 responded “I’m not sure”, and 3 responded “No”. All four students above the age of 18 indicated that they notice when air quality is poor. Of the next oldest age group: 15-17, 7 out of 8 participants responded that they notice when the air quality is poor. Every response recorded as “I’m not sure” or “No” came from students younger than 14. The majority of the older participants conveyed that they are aware of poor air quality, suggesting a correlation between age and air quality awareness. This emphasizes the necessity for younger individuals to learn about air quality and its effects on the environment and themselves. These findings underscore the importance of incorporating air quality education for younger age groups, ensuring that they develop awareness, to foster environmental consciousness.

Figure 4 illustrates that approximately 57.6% of participants indicated that air quality sometimes or often affects their mental health. Analysis of the responses revealed that 6 out of the 11 students who are “Never” affected by air quality were either under the age of 14. The only participant who reported being “Often” affected by air quality was in the 18-20 age range. It is possible to infer that younger participants, perhaps due to a lack of comprehensive understanding regarding air quality, demonstrate a lower reported impact on their mental health. It additionally suggests a potential correlation between age and perception of air quality’s impact on mental health.

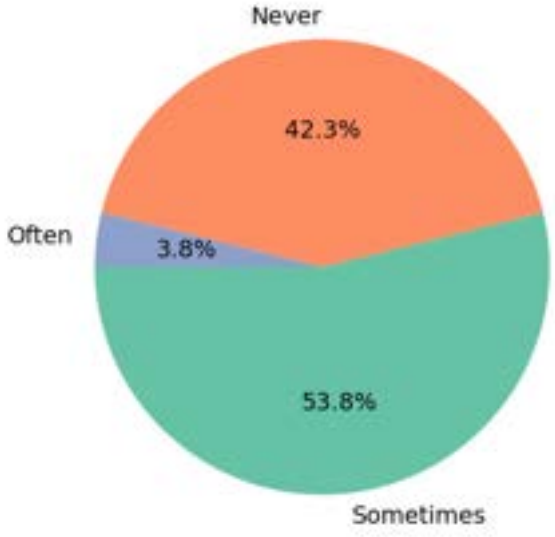

Figure 4: How much Air Quality affects Mental Health

Limitations

This scientific study, conducted on a small scale, encountered several notable limitations during project execution. One major limitation of this study was the minimal access to a diverse participant pool, which may have impacted the data results. Many of the participants were from California as opposed to different places in the United States. Upon reaching out to various schools, it became clear that most schools weren’t interested in participating in the questionnaire because of the perceived absence of tangible benefits for each educational institution.

Furthermore, the survey consisted of questions that required the participants to provide a deeper level of honest reflection. As the researcher, it was not possible to guarantee each participant's honesty, and variations based on each participant's perception of the survey's wording introduced a bias that may have influenced the study results. For the self-analysis questions in the survey, there were many uncontrollable variables in each participant's life, so air quality may not be a prominent factor. Factors such as mental health changes as a response to situations in one's personal life, and individual sensitivity to various environmental factors contributed to the complexity of drawing direct correlations with AQI.

To analyze the responses and put together the data with corresponding AQI values from PurpleAir, each participant provided their city and state location. The analysis revealed that due to multiple PM2.5 sensors in each city, the sensor used for data collection might not have been the closest to the participants' actual locations. This may alter the accuracy of the AQI data depending on the size of each city and the various number of sensors, as the accuracy of the collected data was compromised.

Another unknown variable is the time each participant spent outdoors, since the data incorporated outdoor air quality values, further complicating the interpretation of results. The lack of information regarding participants' outdoor activities introduced uncertainty since exposure to air pollutants outdoors differs widely for each individual. These limitations collectively underscore the need for a cautious interpretation of the study's findings and suggest avenues for improvement in future research endeavors.

Conclusions

This paper elucidates a survey of the potential effects that air quality has on students' productivity, motivation, and mental health. Using samples of data from the questionnaire, there is evidence that poor air quality correlates with a decrease in productivity, motivation levels, and mental health. Through the improvement of outdoor air quality, students may experience an increase in academic stimulation and success, allowing for further mental health improvements. The negative effects that air pollution has on students may have life-long impacts on their careers, which is why this issue needs to be actively addressed. The results therefore suggest that society's focus on the effects of air pollution should be extended beyond the immediate, acute health effects. Additional research in this field is necessary to investigate if there are broader implications regarding air quality and its connection to student academic performance and mental health. With more resources, it would be possible to expand the scope of the project to target a worldwide population to access data from different types of locations. Also, an additional study should extend the time-span for data collection, to include varying AQI values.

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Large Language Models as Zero Shot Forecasters: Verification on DC Motor Trajectories
by Justin Zhang and David Bombara

Abstract

In this project, we studied the ability of large language models (LLMs) to predict the behavior of electric motors via a "prompt" of the motor state history in time. Traditionally, large language models have been used, as the name implies, for predicting future words, given a prompt in natural language. However, recent studies have shown that LLMs can act as time series forecasters that can predict, for example, weather patterns. Similarly, we studied the ability of LLMs to predict the behavior of a linear dynamical system, specifically the electric DC motor. We used GPT-3.5. Specifically, we gave ChatGPT a prompt which was a sequence of numbers corresponding to the motor position and motor velocity versus time. We asked the LLM to output the future motor angle and motor velocity. We had explored different prompting methods such as explicitly telling the language model about our system, i.e that it is a motor. We also studied the output of the language when we only fed it a sequence of numerical values as its prompt.

Introduction

Algorithm-controlled motors are ubiquitous in many mechatronic systems. They can easily fulfill certain tasks, such as the Adaptive Robust Control Algorithm for Linear Motor Drive Systems [1]. In these motor control algorithms, traditional control theory gives us tools for modeling the behavior of DC motors under a given voltage input. We also have strong tools for controlling and estimating the states of DC motors, both in terms of mathematical tools and experimental procedures, such as the optimal parameter estimation for DC motors via a genetic algorithm [2]. We are able to predict the electrical signals of DC motors via time series forecasting [3]. However, the rapid development of control technology has an impact on all areas of the control discipline [4], including the possibility of implementing large language models (LLMs) to control and predict the behavior of DC motors.

The application of LLMs have garnered increasing attention in the field of robotics amidst their swift progress and extensive proliferation [5]. LLMs have been shown to achieve good performance predictions based on time series data [6]. The public LLM model Open LLaMA [7], while inferior to GPT-4's predictive capabilities [8], could forecast financial time series with its outstanding knowledge and reasoning abilities [9]. Thus, LLMs have the ability to work with time series data if activated correctly. TEST, a protocol, can embed time series data, creating prompts to make LLMs open to embeddings, then implements the task, essentially demonstrating the maximum potential of LLMs in regards to time series tasks without compromising the language ability [10]. While the forecasting tasks the LLMs are assigned to widely vary, predicting time series data of DC motors is included in the range.

Understanding LLMs and their ability to predict time series data is crucial in uncovering the new capabilities for language models. While new language models are being developed and updated, older models should be tested for their own abilities to serve as a comparison for the

developing models. This type of measurable improvement in prediction accuracy compared to past versions allows LLMs to be involved in improved operations in many systems and actuators. In our case, the better prediction accuracy of time series data in regards to DC motors leads to better operation of robotic and mechatronic systems. After enough years of development, LLMs working with DC motors would lead to full automation of certain mechatronic devices, giving them a life of their own.

In this work, we aim to use standard language models in predicting basic performance in DC motors, and study the capability of the LLM in that field. This way, we are able to understand the LLM's current role as well as its potential in time series forecasting, without regarding the highly advanced feats that highly advanced LLMs perform via highly advanced protocols. The work will gauge LLMs' ability to forecast data without the need of complex procedures in hopes of future LLMs to accomplish the same feats with simple human instruction.

Approach

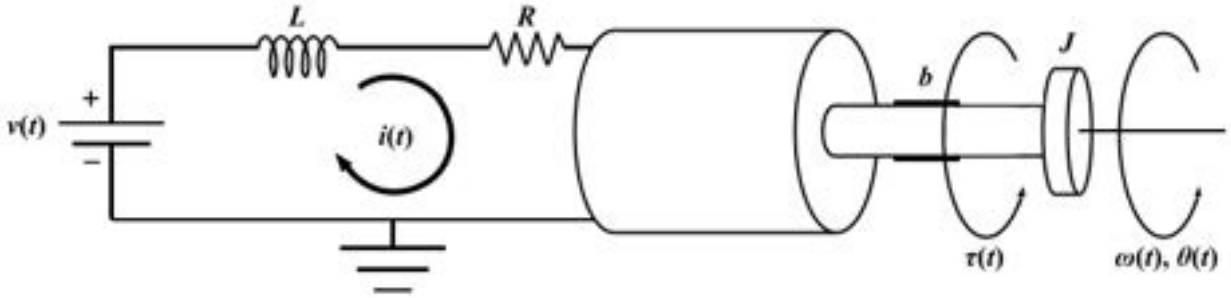

Fig 1: A simple Armature-controlled DC motor with several properties.

The electrical subsystem of a simplified model of an armature-controlled DC motor can be modeled as:

$$L\frac{d}{dt}i(t) + Ri(t) = v(t) \tag{1}$$

The mechanical subsystem can be modeled as:

$$J\frac{d^2}{dt^2}\theta(t) + b\frac{d}{dt}\theta(t) = \tau(t) \tag{2}$$

where the motor torque is given by $\tau(t) = k_\tau i(t)$. Numerical values for the parameters of the system are as follows: inductance $L = 1H$; resistance $R = 2\Omega$; moment of inertia $J = 1\ kg\ m^2$; viscous damping coefficient $b = 1\ N\ m\ s$; and $k_\tau = 2\ N\ m/A$. Note that this model neglects back emf during operation.

The transfer function for the motor is given by:

$$\hat{g}(s) = \frac{\hat{\theta}(s)}{\hat{v}(s)} = \frac{2}{s^3+3s^2+2s} \tag{3}$$

where $\hat{g}(s)$ is the transfer function of the system. The derivation is provided as follows:

$$L\left\{L\frac{d}{dt}i(t) + Ri(t) = v(t)\right\} \Rightarrow Ls\hat{i}(s) + R\hat{i}(s) = \hat{v}(s)$$

$$Js^2\hat{\theta} + bs\hat{\theta} = k_\tau \hat{i}(s)$$

$$\frac{\hat{v}(s)}{\hat{i}(s)} = Ls + R$$

$$\hat{\theta}(s)\left(Js^2 + bs\right) = k_\tau \hat{i}(s)$$

$$\frac{\hat{\theta}(s)}{\hat{i}(s)} = \frac{k_\tau}{Js^2+bs}$$

$$\frac{\hat{\theta}(s)}{\hat{i}(s)}\ \frac{\hat{i}(s)}{\hat{v}(s)} = \frac{k_\tau}{\left(Js^2+bs\right)(Ls+R)} = \hat{g}(s)$$

$$\hat{g}(s) = \frac{k_\tau}{JLs^3+RJs^2+bLs^2+Rbs}$$

$$\hat{g}(s) = \frac{k_\tau}{JLs^3+(RJ+bL)s^2+Rbs} \tag{4}$$

Substitute in constants to obtain:

$$\hat{g}(s) = \frac{\hat{\theta}(s)}{\hat{v}(s)} = \frac{2}{s^3+3s^2+2s} \tag{5}$$

State Space Realization: The state space model is given as a set of two equations, the state equation (Eq. 6) and the output equation (Eq. 7).

$$\dot{x} = Ax + Bu \tag{6}$$

$$y = Cx + Du \tag{7}$$

State-space realization requires the first-derivative of each state variable to be a linear combination of the state variables, plus a term proportional to the input. Thus to derive the state space equations for $[q_1\ q_2\ q_3] = [\theta\ \dot{\theta}\ \ddot{\theta}]$, the following equations are first developed:

$$\dot{\theta} = a_{11}\theta + a_{12}\dot{\theta} + a_{13}\ddot{\theta} + b_1 u(t) \tag{8}$$

$$\ddot{\theta} = a_{21}\theta + a_{22}\dot{\theta} + a_{23}\ddot{\theta} + b_2 u(t) \tag{9}$$

$$\frac{d^3\theta}{dt^3} = a_{31}\theta + a_{32}\dot{\theta} + a_{33}\ddot{\theta} + b_3 u(t) \tag{10}$$

where $a_{i,j}$ and b_i are scalar coefficients for $i = \{1,\ 2,\ 3\}$ and $j = \{1,\ 2,\ 3\}$. By inspection, it can be seen that $a_{11} = a_{13} = b_1 = a_{21} = a_{22} = b_2 = 0$. Similarly, $a_{12} = a_{23} = 1$. The task is to now find the coefficients of Eq. 10. To do so, the transfer function from Eq. 4 will be rewritten to equal $L\left\{\frac{d^3\theta}{dt^3}\right\} = s^3\hat{\theta}(s)$.

$$s^3\frac{\hat{\theta}(s)}{v(s)} = \frac{s^3 k_\tau}{JLs^3 + (RJ+bL)s^2 + Rbs} \tag{11}$$

$$= \frac{k_\tau}{JL + \frac{1}{s}(RJ+bL) + \frac{1}{s^2}Rb} \tag{12}$$

$$s^3\hat{\theta}(s)\left(JL + \frac{1}{s}(RJ + bL) + \frac{1}{s^2}Rb\right) = k_\tau v(s) \tag{13}$$

$$JLs^3\hat{\theta}(s) + (RJ + bL)s^2\hat{\theta}(s) + Rbs\hat{\theta}(s) = k_\tau v(s) \tag{14}$$

Taking the inverse Laplace transform of Eq. 14,

$$JL\frac{d^3\theta}{dt^3} + (RJ + bL)\frac{d^2\theta}{dt^2} + Rb\frac{d\theta}{dt} = k_\tau v(t) \tag{15}$$

Solving for $\frac{d^3\theta}{dt^3}$,

$$\frac{d^3\theta}{dt^3} = -\frac{(RJ+bL)}{JL}\frac{d^2\theta}{dt^2} - \frac{Rb}{JL}\frac{d\theta}{dt} + \frac{k_\tau}{JL}v(t) \tag{16}$$

$$= a_{31} + a_{32}\frac{d\theta}{dt} + a_{33}\frac{d^2\theta}{dt^2} + b_3 u(t). \tag{17}$$

Therefore, $a_{31} = 0$, $a_{32} = -\frac{Rb}{JL}$, $a_{33} = -\frac{RJ+bL}{JL}$, $b_3 = k_\tau$, and $v(t) = u(t)$. The state space model of the system may now be written as:

$$\begin{bmatrix}\dot{q}_1 \dot{q}_2 \dot{q}_3\end{bmatrix} = \begin{bmatrix}0\ 1\ 0\\ 0\ 0\ 1\\ 0\ -\frac{Rb}{JL}\ -\frac{RJ+bL}{JL}\end{bmatrix}\begin{bmatrix}q_1 q_2 q_3\end{bmatrix} + \begin{bmatrix}0\ 0\ k_\tau\end{bmatrix}u \tag{18}$$

$$y = [1\ 0\ 0]\begin{bmatrix}q_1 q_2 q_3\end{bmatrix} \tag{19}$$

By substituting in values for the constants, the state space equations may be written as,

$$\begin{bmatrix}\dot{q}_1 \dot{q}_2 \dot{q}_3\end{bmatrix} = \begin{bmatrix}0\ 1\ 0\\ 0\ 0\ 1\\ 0\ -2\ -3\end{bmatrix}\begin{bmatrix}q_1 q_2 q_3\end{bmatrix} + [0\ 0\ 2]u \tag{20}$$

$$y = [1\ 0\ 0]\begin{bmatrix}q_1 q_2 q_3\end{bmatrix} \tag{21}$$

The **controller canonical** realization will yield this state-space model (Eq. 20) from the transfer function. This system is guaranteed to be controllable because the input enters a chain of integrators that can change every state.

DC Motor Model

In our experiment, 3 of the motor's states were simulated, being the angular position, velocity and the acceleration. For these, the state space format was used to model these properties (as the basic DC motor exhibits linear behavior in terms of control systems) [11]. The DC motor is a linear continuous time-invariant system, but for the purposes of simulation, we converted it to a discrete time system. Specifically, we applied control inputs at a rate of 1000 Hz, such that each time step lasted for a duration of 0.001 seconds.

Large Language Model

GPT-3.5, while an "improved" version of GPT-3, is considered a general-purpose language model and relies on a vast knowledge base drawn from online and offline sources. This generative large language model will be used in the experiment not only due to its accessibility to users, but also due to its powerful generative capabilities with the greatest impact today [12]. As it is based on the transformer language architecture, GPT-3.5 should be able to weigh certain words and make connections with data inputted via a prompt. Capabilities like the zero-shot generalization [6] in the language model can be used for time-series forecasting.

Experimental Procedure

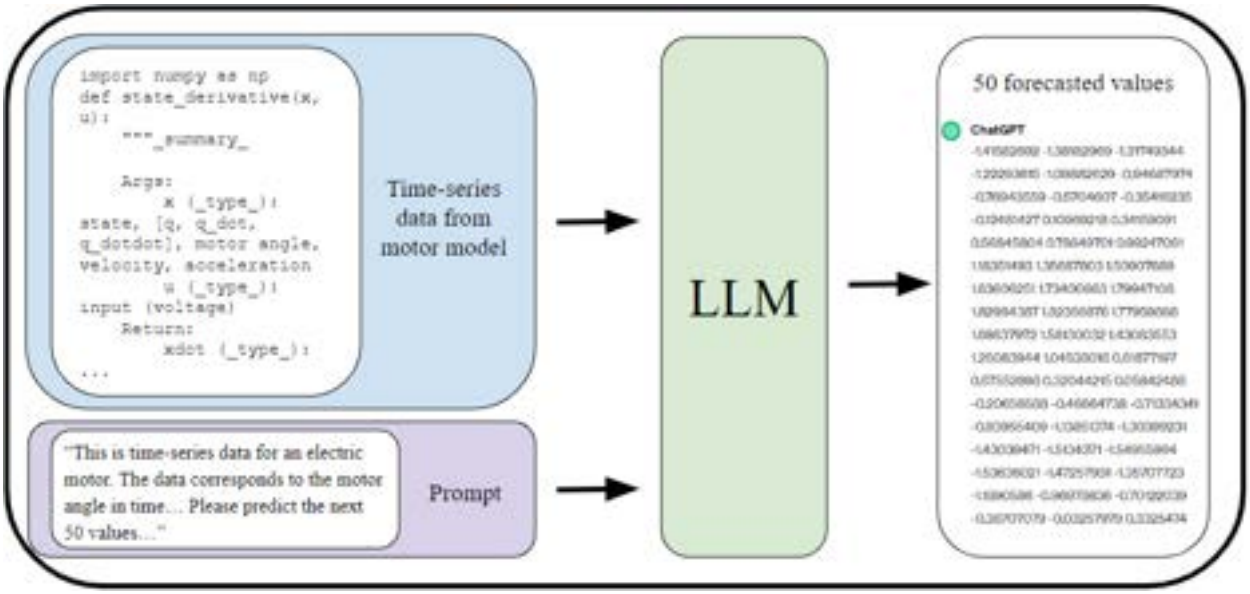

Fig 2: A simple block diagram of the experiment. By feeding both the generated time-series data from the motor model and the specifically worded prompt into GPT-3.5, we are able to obtain 50 forecasted values of the DC motor time-series data.

Our experiment involved the use of Visual Studio Code in the language of Python, as well as ChatGPT. In the Visual Studio Code editor, with the help of the Numpy library, several equations from the DC motor model (such as Eq. 17) were integrated into the system, which would result in an output of a 1D time-series array. The 4 properties that came in an array were the motor's angle, velocity, acceleration, and voltage. In these 4 arrays, each element in the array corresponded to the motor's specific state according to time, at an interval of 0.001 seconds for 22.5 seconds. With the help of the Pyplot library, these time-series arrays could be plotted, thus resulting in the original DC motor property values which the LLM would be compared to.

The generated time-series arrays (which included every 150th value of the generated values) would be repurposed as the main portion of data fed to the LLM, alongside a prompt, which would direct the LLM into using its pure prediction capabilities rather than using a simple solution, such as curve fitting. The prompts followed a basic format, with the data inputted first, followed by a brief description of the data, then lastly requesting 50 more elements. (Ex: This is

time-series data for an electric motor. The data corresponds to the motor (angle / voltage / velocity / acceleration) in time. Please predict the next 50 values in the time series data directly. Do not write python code or use curve fitting. In your response, include no other information other than your predictions.) The resulting values would be graphed in comparison to the time-series data derived from our model equations.

Experimental Results

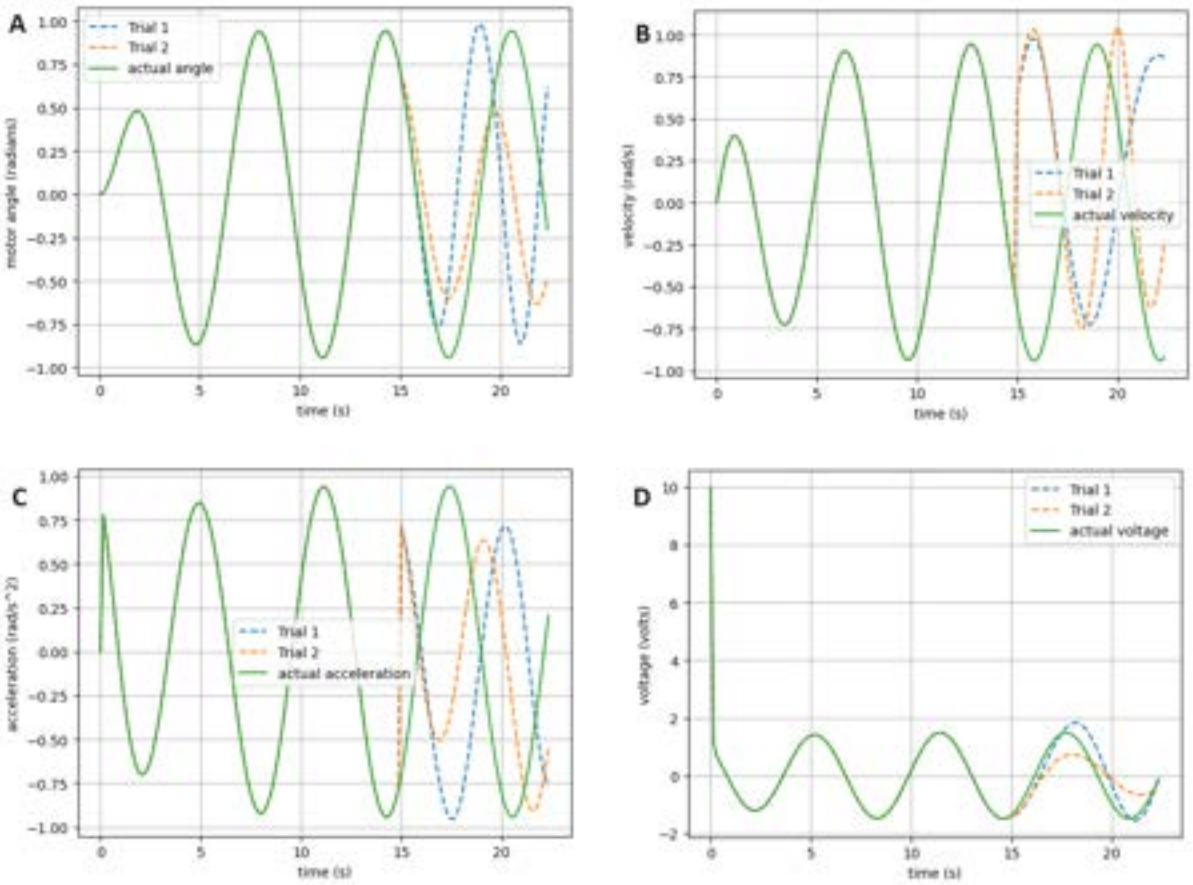

Fig 3: Figures A, B, C, and D show the graphs (above) of both trials versus the motor model output for the motor angle, velocity, acceleration, and voltage respectively.

The desired motor angles, velocities, accelerations, and voltages in Figures 3A, 3B, 3C, and 3D was a sinusoid, but the simulated motor angles were shortened, as if it were a compressed sinusoid. Each trial had different anti-nodes, and Trial 1 had a generally larger amplitude than Trial 2. In Figures 3B and 3C, while the desired motor property (either the velocity or acceleration depending on the Figure) continued its sinusoidal pattern, the two trials both jumped in magnitude, mimicking the behavior of the desired motor property at the beginning of the graph. In Figure 3D, both trials continued to mimic the sinusoidal pattern while ignoring the sharp change at the beginning, unlike Figures 3B and 3C.

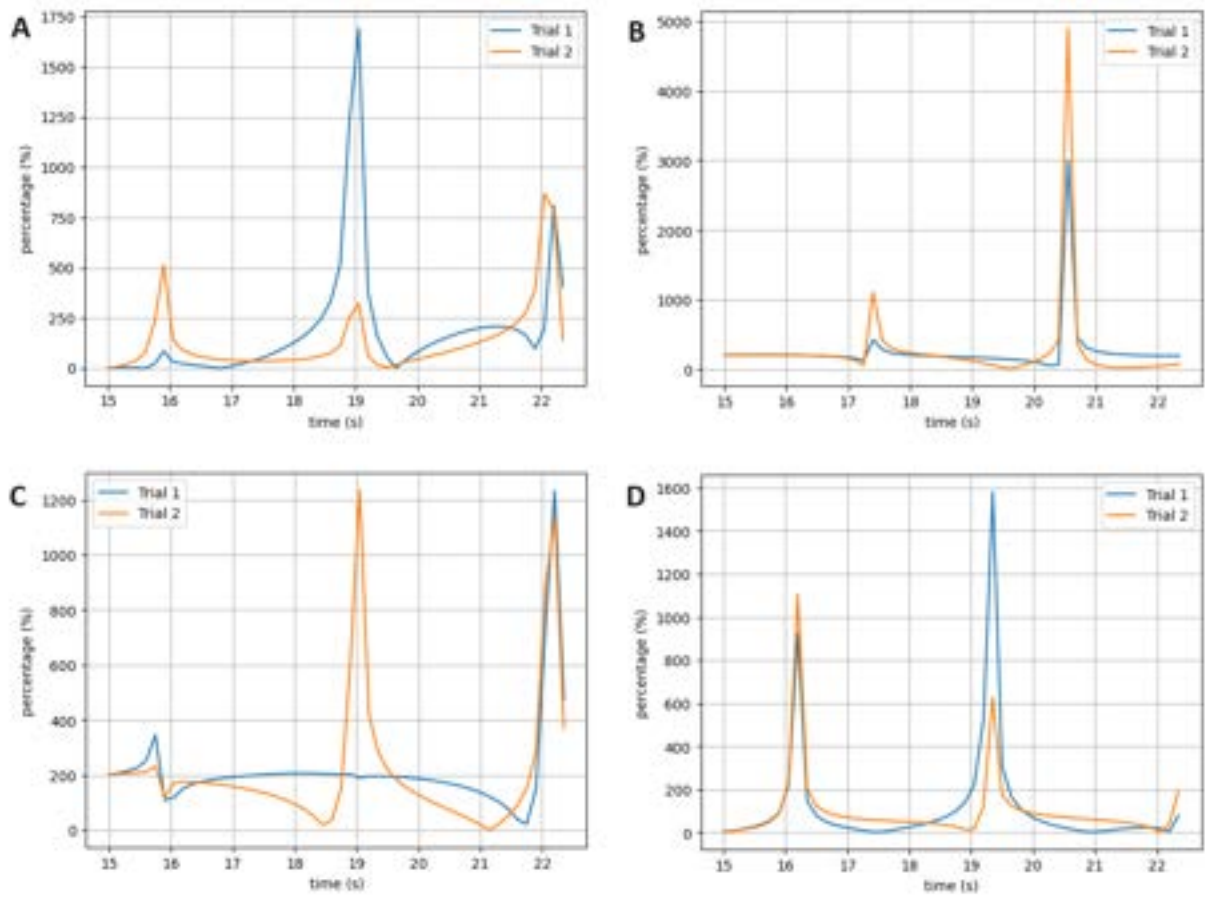

Fig 4: Figures A, B, C, and D show the percent error (above) of the two trials compared to the motor model graph for the motor angle, velocity, acceleration, and voltage respectively.

The large inaccuracies between the trials and the desired motor states could be seen as spikes in the percent error graphs in Figures 4A, 4B, 4C, and 4D. Both trials had high inaccuracies in all 4 graphs.

Discussion

From the experimental results, the LLM somewhat predicted the angle, voltage, velocity, and acceleration of the DC motor. While the time series graphs initially followed the curve, as more data was generated the LLM strayed further from the actual curve. Although the percentage graph showed large amounts of errors, even reaching up to a 1600% error, the likely cause was due to the original data having very small values (for example, a predicted value of 0.2 is 0.18 larger than the actual value of 0.02, but in terms of percent error it is 900%). Most importantly, the graphs show that while the LLM fails to accurately predict the behavior of the DC motor, it had a reasonable accuracy for the initial data it was provided with.

Even though the experiment was run, and GPT-3.5 displayed its capabilities in forecasting the time series data, our work was limited as we didn't implement an extreme variety of testing, instead only focusing on the basics of the DC motor. Although the two trials resulted

in similar precision according to the time series graphs, with exception to certain spikes in the data, further tests could be run. GPT-3.5 was a strong candidate for this sort of testing, but a stronger measurement could be pulled from using similarly capable LLMs.

Conclusion

Despite having an understanding of the predictive capabilities of time series data of a DC motor, algorithms can be trained to predict more accurately. An example would be LLM4TS, which takes pre-trained LLMs and turns them into efficient time series forecasters [13]. This alignment would improve GPT-3.5's ability in regards to DC motors. While the results of the experiment apply only to DC motors, further work could be generalized to a wider class of dynamical systems, such as possibilities found in linear and non-linear systems [14]. In other words, we would examine breakthroughs in forecasting time series data (as LLMs revolutionize time series forecasting [15]), and examine if common LLMs could do the same, whilst gauging their performance in that task.

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3D Printing and Biodegradable Materials for Sustainable Architecture by Kiran Rao

Abstract

Current construction procedures and industry standards have harmful effects on the environment and contribute to the climate crisis; alternatives must be considered and developed. Additive manufacturing is the process of 3D printing and construction by depositing material in consecutive layers. Biodegradable materials are com- pounds that can be decomposed by smaller micro-organisms and are capable of naturally assimilating into the environment. Both of these technologies are individually established in the architecture industry. However, the intersection of these two methods holds extreme potential to produce environmentally friendly and sustainable construction. Biodegradable materials are additively manufactured into components and structures that can be utilized for large-scale architecture. This paper presents the most significant research discoveries and litera- ture in this developing field. Specifically, advancements in mycelium, bacterial cellulose, chitosan and earthen material compounds for additive manufacturing and production of biodegradable architecture are extensively re- viewed. Resources and information were accessed via online databases such as ”Google Scholar”, ”Mendeley” and ”Science Direct”. Concerns and complications such as structural stability, longevity and internal supports are explored. Knowledge gaps and disadvantages will be identified; possible solutions and concepts for experimen- tation will be proposed. Finally, further innovation and research that must be conducted will be discussed.
Keywords: 3D printing, additive manufacturing, biodegradable materials, biodegradable architecture, sustainable construction

Introduction

The climate crisis continues to emerge as a pressing issue that calls for immediate intervention. The large role that the architecture and construction industry plays in the climate crisis must be addressed. It is estimated that 34% global energy consumption is devoted to the construction and maintenance of buildings (“Buildings - Energy Sys- tem”, n.d.). Vice-versa, the climate crisis has large-scale effects on the built environment. Extreme weather events, such as flooding, wildfires and unpredictable temperature changes, threaten the stability of existing structures and require significant energy and monetary investments for repairs (US EPA, 2022). The climate crisis exacerbates these climate events and increases their frequency. New types of structures and materials, such as naturally sourced and biodegradable materials, that can withstand and react to harsh environments must be found.

Individual progress in the fields of additive manufacturing and biodegradable materials for architecture has been ac- complished. 3D printed houses have been printed with concrete while a growing number of projects have sourced biodegradable building materials (Beyhan & Arslan Selc¸uk, 2018; Bondre, n.d.). However, these technologies still have complications that limit their possibility for fully sustainable architecture and minimal climate conse- quences.

Common materials for 3D printing, such as concrete, are harmful and not sustainable and the installation of biodegradable materials can be time-consuming and expensive (Bos et al., 2016; Mitterberger & Derme, 2019). Therefore, when these two technologies and methods are combined, the possibility of sustainable architecture becomes extremely wide-ranging. These technologies solve the drawbacks of the other; unfavorable extrusion materials are replaced with biodegradable materials and the slow, expensive installation processes are solved with additive manufacturing (Ho et al., 2023b). The potential for these methods to complement each other and produce desirable results is promising.

Changing the current destructive relationship between the climate and infrastructure is essential; existing struc- tures and the climate both suffer. To accomplish this, a complementary interconnection must be fostered. Low- cost, energy-efficient building processes such as additive manufacturing in combination with naturally sourced and biodegradable materials offer a possible solution to this issue. This paper compiles the most significant works, projects and knowledge discoveries in this newly developing field. The author of this paper hopes to synthesize and present this information so that future researchers can direct their work in a meaningful way. Possibilities for further investigation and knowledge gaps that must be explored are discussed throughout the literature review and conclusion sections of this paper.

Methods

Databases such as ”Google Scholar”, ”Mendeley” and ”Science Direct” were used to identify and collect work for analysis. Relevant resources and documents were searched via keyword phrases: ”3D printing”, ”additive man- ufacturing”, ”biodegradable materials”, ”biodegradable architecture”, ”sustainable construction”, ”3D printing in architecture”, ”sustainable 3D printing” etc. These searches were conducted in June-August of 2023. Restrictions were present such as language (English) and electronic availability. Factors such as originality, clarity, relevance to research topic, recency, source and thoroughness were considered in the collection and screening process.

Original experimental research papers were the primary type of work used in this analysis. Multiple resources cov- ering identical topics were examined to verify information and identify inconsistencies. Literature reviews were also considered. Additional information in the form of videos, websites and databases from reputable sources was included.

After reading the collected works, documents and resources were categorized to ensure clarity in the presentation methods. Additional research that was not originally considered was sought out depending on knowledge gaps and missing topics. All data was directly analyzed by the author. The author synthesizes the most significant discoveries and presents uncertainties and concerns.

Literature Review Context and Background Information

Additive manufacturing is the computer-controlled process of creating 3-dimensional objects, parts and structures by successively printing one layer of material on top of another (Zˇ ujovic´ et al., 2022a). The terms “additive man- ufacturing” and “3D printing” are often used interchangeably. The opposite construction method is subtractive manufacturing. This process is defined by material removal through drilling, grinding, cutting and (Mathur, 2016). The largest downfall of subtractive manufacturing is the high material waste. In contrast, additive manufacturing uses the least amount of material possible.

3D printing technology was first introduced in the 1980s (Hager et al., 2016). Until the 2000s, 3D printing was a relatively niche and small field only for experts. In 2005, the technology was commercialized and became avail- able to consumers. Additive manufacturing has wide-reaching applications; it has already been utilized in medical, engineering, dental, aeronautic and production fields (de Leo´n et al., 2023; Hager et al., 2016). 3D printing has begun to emerge in the architectural field in the past decade/s. One of the most promising aspects of additive man- ufacturing is its unique ability to balance mass production along with customization and tolerance. As opposed to traditional manufacturing machines that are designed to complete and only complete one step of the process, 3D printing machines can create countless types of products without the need for adjustments to the machine (Mathur, 2016). Therefore, the technology is suitable for creating infrequent, customizable and unique products. However, it can still produce products at a rapid pace and when multiple printers work together, its efficiency rivals traditional factory production.

3D printing and additive manufacturing processes are newly-developing methods that can solve many of these problems. 3D printing is an automated process that reduces the cost and carbon footprint of construction. Other benefits include time savings, reduced energy usage and minimized industrial waste (Hager et al., 2016). Fur- thermore, 3D printing is significantly safer for workers because less manual labor is required. Work sites can be hazardous to laborers; workers are at constant risk (Bos et al., 2016). In 2021, 2,600,000 injuries and illnesses were reported in the private industry sector (“IIF Latest Numbers”, n.d.). Additionally, 5,000 construction-related fatalities across all sectors were reported in 2021 (“IIF Latest Numbers”, n.d.). Less humans will be required to oversee the additive manufacturing of structures and they will be placed in fewer dangerous situations. Current construction processes are time-consuming, expensive and dangerous.

It is important to note that 3D printing technology has already become widely accepted in the architecture industry during the design phase. Additive manufacturing is a common tool for prototyping, small-scale modeling and design thinking iteration. Furthermore, the interior design industry utilizes 3D printing as a common production technique. Products such as seats, lamps, desks, artwork, vases and large-scale hanging artwork are common ap- plications for this technology. However, this paper focuses on the use of 3D printing as the main fabrication and construction system for structural components.

Current, industry-leading building materials are often permanent and not sustainable. When buildings are con- structed, their production method does not consider the lifespan and

future of the structure. Instead, they prioritize short-term goals such as expense, speed and ease. Ultimately, after the demolition of these buildings, the materi- als are no longer usable or valuable and wastefully discarded, unnecessarily jeopardizing the environment. Some resources can be reprocessed for different purposes: bricks and concrete for rubber soling and wood for veneers. However, these recycling processes are selective and not commonly employed.

Instead, bio-based and naturally sourced materials must be utilized to mitigate the long-term environmental effect of construction. Impermanent materials are important to commercialize considering the short lifespan of many buildings. However, it is difficult to develop structurally strong materials that have load-bearing capacities, are capable of withstanding harsh environmental conditions and are sustainable and green. This is an important topic to invest time and resources in because of its possibility to alleviate the construction industry's effect on the envi- ronment.

Furthermore, popular building materials are destructive beyond the waste they leave behind. For example, the con- crete production process is extremely energy intensive (Bos et al., 2016). Additionally, concrete damages topsoil and leads to erosion. Brick-firing processes large amounts of CO2 into the atmosphere (Bos et al., 2016). Naturally sourced and bio-based materials are ideal for construction because they have limited environmental consequences, unlike current substances.

Mycelium and Fungal Constructions

Mycelium is one of the leading naturally occurring and sourced materials for architectural usage. "Mycotechnolo- gies" is the field and methods that utilize mycelium for sustainable architecture and remediation (Karimjee, 2014). The larger part of the fungus that grows under the mushroom top is called mycelium. Mycelium fosters a healthy relationship with its ecosystem by regenerating soil and creating an environment for other plants to grow; it is able to accomplish this by breaking down and recycling the nutrients in wood. During the decomposition of wood, the mushroom sprouts. The mushroom then produces spores into the air that eventually germinate and contribute to a new mycelium mat. When the fungus is in a suitable environment, the mycelium network acts as glue and creates a large network of roots that solidifies and cements the substrate (Elsacker et al., 2022). The mycelium network can bind the substrate together, giving it a solid form and structure. We have the ability to expand upon the already existing interdependent relationship between the environment and mycelium/fungi by extending its applications into architecture.

Like most fungi, mycelium only grows in the presence of a substrate that provides the necessary nutrients for growth (FIGURE). Mycelium first must undergo substrate inoculation where it is provided with these resources. This can take the form of drilling holes into logs, cutting wedges or directly mixing together spawn with the sub- strate (Spellman-Lopez, n.d.; "Understand Mushroom Inoculation for Cultivating Mushrooms", 2020). However, for experimental purposes, it often occurs on a small scale such as a petri dish to prevent

contamination and is transferred to larger structures and frameworks as it develops and grows. The substrate must be sterilized before exposure to the fungus; this ensures that no other microscopic organisms previously embedded in the substrate will compete against the mycelium network for resources. In certain cases, a pasteurization process (exposure to high temperatures) is sufficient . Otherwise, an in-depth and intricate sterilization process must occur. Sub- strate inoculation methods can directly shape the final form of mycelium (Vallas & Courard, 2017). For example, the substrate inoculation phase can occur on a cardboard sheet in order to fabricate a thin layer of mycelium. Mycelium growth can be stopped through a drying/heating process ("Understand Mushroom Inoculation for Cul- tivating Mushrooms", 2020). When exposed to high temperatures, mycelium bacteria are killed and growth rates decrease significantly. An overview of Mycelium in different scales and stages is presented in Figure 1.

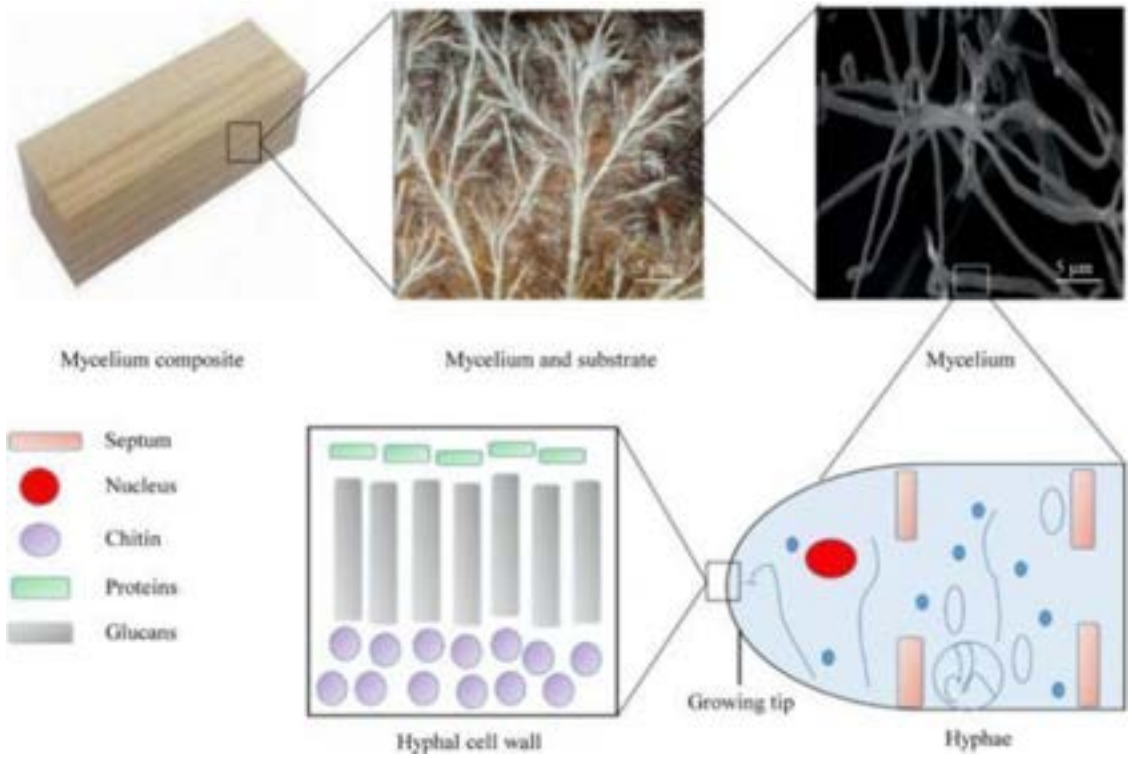

Figure 1: Mycelium at different scales
Gibson, LJ. (2021). Example of how the mycelium and substrate look in a mycelium composite.png [diagram].
Wikimedia Commons. https://upload.wikimedia.org/wikipedia/commons/5/5d/Example of how the mycelium and substrate look in a mycelium composite.png

Many applications and possibilities for mycelium to be utilized in architecture exist; one of these is the develop- ment of “mycobricks” (Karimjee, 2014). Mycologist Paul Stamets invented a method to fabricate mycelium and mushrooms into building blocks/bricks (“6 ways mushrooms can save the world — Paul Stamets”, 2008). These bricks are fireproof, mold and water-resistant and excellent insulators. Furthermore, the bricks are extremely strong when constructed together and have more structural stability than alternative mycelium production techniques. Un- pasteurized and live bricks can grow together and intertwine once they are placed next to each other, filling the gaps between blocks. Bricks that are pasteurized can be connected through pegs and structural supports. “Myco- bricks” can survive multiple years, even when exposed to harsh environmental conditions. When in contact with the ground, they can decompose within 6 weeks depending on soil humidity and insect activity (Karimjee, 2014).

Traditional applications for mycelium in architecture rely on the growth of the organism through molds (Elsacker et al., 2022). Fibers must be placed inside the growing space for the mycelium to receive the necessary nutrients. A study examined the effects of different fiber types as

well as the condition in which they were presented (El- sacker et al., 2019). Dust flax and dust straw resulted in poor growth during both the first and second growing periods. Samples with flax and hemp were the most effective and reliable for promoting growth. Additionally, further growth can be achieved by improving the air circulation inside the molds (Elsacker et al., 2019).

However, this same study concluded that fiber condition was more important in determining the compressive strength and stiffness of mycelium structures than the fiber type (Elsacker et al., 2019). Fibers prepared in a chopped or pre-compressed state grew the most effective mycelium for undergoing compression (Elsacker et al., 2019). This is because the fibers were in a more dense state than loose or unchopped. This promoted more growth in the inner layers and core of the mycelium structures. Pre-compressed materials performed better than alterna- tives in compression tests (Elsacker et al., 2019).

Hemp-based composites stand out as a possible insulation material with the lowest thermal conductivity of the materials tested (Elsacker et al., 2019). Furthermore, water absorption tested low when the hydrophobic outer layer was sufficiently developed (Elsacker et al., 2019). Ultimately, it was found that the mechanical and structural properties such as compressive stiffness, water absorption rates and thermal conductivity of mycelium were more directly affected by the fiber condition, size and processing than they are by the chemical composition of fibers (Elsacker et al., 2019). In the future, other properties of insulating materials must be considered and tested such as acoustics, water-vapor diffusion and fire resistance. The enhancement of these properties will result in more effective and suitable insulating materials.

Unfortunately, mycelium growth through molds has many disadvantages and limitations. The living material tends to migrate toward the exterior and surface of the mold. This is because the organism is searching for oxygen; ulti- mately, this leads to restricted and underdeveloped growth in the core of the structure. Furthermore, a secondary step of growth is required to build up fungal skin. The fungal skin is the outermost layer and is essential for its binding and water absorption properties. Mycelium must be grown in its final desired geometry from the start. This often limits the customization and scale of the end product. Lastly, oftentimes molds are not reusable and produce large amounts of waste, leading to an unsustainable process (Elsacker et al., 2022). Very few large-scale mycelium products have been produced and mycelium-based products through regular mold construction have a general maximum thickness of 150mm because of the organism's requirements for oxygen circulation and intake (Elsacker et al., 2021). Therefore, other methods must be researched.

Although mycelium applications through mold production techniques are limited, many projects have success- fully utilized fungal biomaterials such as mycelium for the assembly of structures and buildings. These works are proof of concept and have produced significant technological knowledge. The Hy-Fi pavilion, built in the Museum of Modern Art, was the largest construction project with mycelium composite materials, employing over 10,000 blocks (Saporta & Clark, 2016). After the demolition of this structure, the bricks degraded within 60 days (Saporta & Clark, 2016). The "growing" pavilion is a cylindrical structure with outer walls made of mycelia pan- els (Pownall, 2019). Many other bio-based materials in addition to mycelium panels were used

to obtain water resistance and structural stability. The MY-CO SPACE was a prototype for temporary dwelling of two residents (Meyer et al., 2022). 300 mycelium coated products were utilized and milled plywood was used as the substrate to promote mycelium growth. This structure utilized bolts, metal parts and other hardware, rendering it not fully biodegradable. Other applications for mycelium in the architectural industry include its use as the outermost mate- rial. Mycelium is inoculated directly onto cardboard sheets. These sheets would support the growth of mycelium and eventually evolve into a living, organic material (Vallas & Courard, 2017). These sheets/panels could then be used as an insulating and protective layer for the exterior of houses.

One of the most novel fabrication techniques takes advantage of Mycelium's self-healing capabilities and migration toward aerobic zones (Elsacker et al., 2021). Mycelium directly responds to damage by reinforcing and re-growing branches, creating a stronger and more robust network of hyphae. Therefore, the artificial trimming of hyphae re- sults in stronger and denser growth of mycelium networks. Scientists have utilized robotic abrasive wire-cutting technology to promote this method of growth (Elsacker et al., 2021). This technology can be considered nearly zero waste as trimmed mycelium can be used for the growth of new and separate networks. Additionally, scientists can customize the final product's shape by trimming, slicing and cutting the structure (Elsacker et al., 2021). Similarly, the fracturing or damage to the interior of a mycelium network results in the stronger regeneration of the network (Elsacker et al., 2021). These self-healing properties can be exploited to produce denser and stronger products.

One mycelium fabrication solution stands out for its usage of additive manufacturing technologies (Elsacker et al., 2022). A significant part of this technique is the preparation of the extrudable filament. In this experiment, mycelium is incubated with rye bran and then wood dust (Elsacker et al., 2022). Additionally, feedstock, water and a gelling agent are mixed together and sterilized (Elsacker et al., 2022). This mixture is used for the inoculation of mycelium with wood dust (Elsacker et al., 2022). Furthermore, a viscous agent is added and then mixed in with the pre-grown substrate after the incubation process is complete (Elsacker et al., 2022). This viscous agent is important to ensure that a paste-like substance capable of being extruded is produced. Without the viscous prop- erty, the extruded materials would not stick together and hold their form while network growth occurs. Mycelium paste presented many challenges in the development of this technology (Elsacker et al., 2022). The filament often clogged was extruded inconsistently or unpredictably (Elsacker et al., 2022). A homogenous, extrudable solution must be found.

The final mycelium infused paste was extruded through a 5mm cone-like nozzle (Elsacker et al., 2022). The cone shape was most optimal for guiding the paste out of the holding container precisely and consistently. After the printing process was complete, the holding cell for the extruded material was sealed and left to incubate (Elsacker et al., 2022). Once the desired incubation time or growth was achieved, the sample was heated to terminate its growing stage (Elsacker et al., 2022).

Three main parameters and categories that directly influenced the printing process and product were identified: the extrudable solution, the extrusion technique and the extrusion hardware (Elsacker et al., 2022). As previously described, significant efforts were invested in producing the most effective printing solution. Important qualities of the paste include viscous properties,

homogeneous distribution, the concentration of ingredients, the concentra- tion of bacteria, particle size and more (Elsacker et al., 2022). The addition of a viscous agent also complicates the performance of the product after printing and its ability to develop into a healthy mycelium network. The extrusion technique, specifically regarding the toolpath geometry and extrusion pressure, is integral to the final fabrication product (Elsacker et al., 2022). 3D printing a living substance like Mycelium is an extremely novel and unexplored concept; previous common practices for plastic filament printing do not transfer. Toolpaths in the forms of cylinders, parallel lines and cross-layer lines were all explored (Elsacker et al., 2022). Printing a structure with uniform line thickness and consistency is extremely difficult to achieve. Lastly, the hardware and technology used for the extrusion is the largest factor in determining the quality of the printed product (Elsacker et al., 2022). Printing speed, printing velocity, nozzle size, nozzle shape and more must all be considered when designing the most effective robot (Elsacker et al., 2022).

One important challenge was identified in the printing process: the material struggles to support the weight of additional layers and collapses (Elsacker et al., 2022). One solution was to place a temporary infill of sawdust to support the walls of the print (Elsacker et al., 2022). This scaffolding also performed the role of substrate and promoted the growth of mycelium networks (Elsacker et al., 2022). However, this measure may not be easily transferred to a larger scale.

Mycelium production processes lack standardization. Small alterings of any variable throughout its inoculation, sterilization and growth processes can result in large differences in the final product (Elsacker et al., 2019). In the future, standardized processes must be found and improved upon to reliably produce mycelium containing certain characteristics. Different procedures will likely be used depending on the desired qualities of the final product. To achieve this, more research and experimentation on different developmental and growth processes must occur. Specifically, important characteristics such as water resistance and stability/load-bearing capacities must be im- proved upon.

Another opportunity for exploration and research lies in the final treatment of mycelium products. Heating the material kills the organisms and creates a more permanent structure and form (Elsacker et al., 2019). However, the self-healing, self-organizing and self-repairing qualities are lost (Meyer et al., 2022). These properties prove to be extremely valuable for applications in architecture. Autonomous growth, adaptation and self-regulation offer an alternative to modern building techniques that rely on heavy infrastructure and large amounts of technology. Furthermore, mycelium composites lack water-resistance, load-bearing capacities and durability. If mycelium can be engineered to fit these requirements, monolithic and mycelium-based structures will be more practical. Currently, mycelium must be reinforced with other weight-bearing scaffolding or structures (Elsacker et al., 2022; Meyer et al., 2022; Pownall, 2019; Saporta & Clark, 2016; Vallas & Courard, 2017). The application of mycelium as a sole building material moves it into a more sustainable and efficient space.

Lastly, a balance must be struck between the durability and biodegradability of mycelium in the architectural space. Mycelium is an outstanding solution for its biodegradable and natural properties (Karimjee, 2014). How- ever, long-lasting structures that can withstand stress are still

required. Certain mycelium development processes that prioritize durability and performance are necessary in order for mycelium to be a viable and widely-used construction material.

Aguahoja

Aguahoja stands alone as an exceptional work in the intersection between additive manufacturing, biodegradable and naturally sourced materials and architecture ("Aguahoja", n.d.; Ling, 2018; Mogas-Soldevila et al., 2014). This work is a product of the Massachusetts Institute of Technology Media Lab and the Mediated Matter group, led by Neri Oxman. This research ingeniously combined 3D printing technology with biologically sourced poly- mers to produce a large-scale pavilion with comprehensive and direct real-world applications ("Aguahoja", n.d.; Ling, 2018). Aguahoja I is a 5-meter-tall freestanding structure made of a flexible 3D printed bio-composite skin-like material ("Aguahoja", n.d.; Ling, 2018). Multiple phases of the Aguahoja project occurred; this review will primarily focus on the findings and work of the first phase, Aguahoja I.

Biopolymers are naturally occurring polymers. Polymers are any substance or material that is made up of large molecules (macromolecules) and connected together through chemical bonds ("What are Biopolymers", n.d.). The most abundant natural polymers are cellulose and chitin respectively (Derme et al., 2016). Chitin shares a similar chemical structure to cellulose and can be found in the shells and skeletons of insects, crustaceans and other small organisms (Mogas-Soldevila et al., 2015). Furthermore, it can even occur in certain fungi. Chitosan, the material of study, is derived from chitin by treating chitin with an alkaline compound, resulting in a deacetylation process, as demonstrated in Figure 2 (Mogas-Soldevila et al., 2015). Chitosan carries advantages over chitin in the archi- tectural space: high solubility in water and the ability to biodegrade (Mogas-Soldevila et al., 2015). This renders chitosan a far superior material for the fabrication of temporary structures.

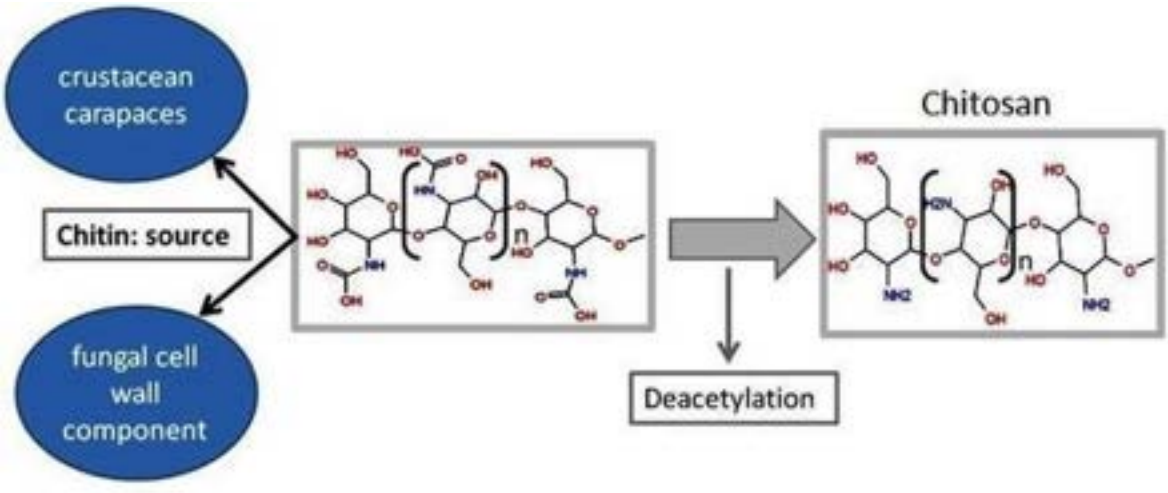

Figure 2: Chemical structure of chitin and chitosan
Neto, V. (2019). Chitin and Chitosan.jpg [diagram]. Wikimedia Commons.
https://upload.wikimedia.org/wikipedia/commons/a/a0/Chitin and chitosan.jpg

Smaller, additional experiments with the purpose of engineering dissociative qualities were performed (Ling, 2018; Tai et al., 2018). Biopolymer composites were used in this study. Chitosan tends to contract and curl when sus- pended in a hydrogel (Tai et al., 2018). However, cellulose remains flexible and provides stability during the drying process. Therefore, a chitosan-cellulose compound was selected as the material for printing (Tai et al., 2018). This composite was printed on top of a pectin base film (Tai et al., 2018). Pectin is a polysaccharide and can be found in fruit skins as well as structural layers of tree trunks and branches. This natural polymer forms a viscous hydrogel that can absorb water. When chitosan-cellulose is printed on top of it, it accelerates the cooling and dehydration process while preventing chitosan's contraction and curling tendencies (Tai et al., 2018). Pectin's natural translu- cent properties play a skin-like role in the structure, filling the gaps between chitosan-cellulose extrusion patterns.

A base layer of pectin composite was printed on top of an anodized aluminum substrate (Tai et al., 2018). After 24 hours at room temperature, the chitosan-cellulose composite was extruded (Tai et al., 2018). Multiple square samples were printed with different grid densities and Euler path methodologies (Tai et al., 2018). After 12 hours, the panels were removed from the substrate, placed in distilled water and observed for 14 days (Tai et al., 2018).

The pectin base layer decomposes before the chitosan-cellulose layers. It was found that grids with higher den- sities of chitosan take longer to disassociate; they hold their shape and diffuse less (Tai et al., 2018). It was also discovered that a dense perimeter is more resistant to dissociation in water (Ling, 2018; Tai et al., 2018). Dense material distribution retains shape more effectively than lower concentrations of the compound (Tai et al., 2018). In addition, computer simulations modeling biopolymers as viscous fluids were conducted. Two important find- ings were discovered: areas with more viscous material dissociate slower and the initial viscosity, rate of change in water and other characteristics of a material have direct relations to the dissociation behavior (Tai et al., 2018).

For the construction of the pavilion, purchased chitosan powder is processed into a gel of concentrations ranging from 3% to 12% (Mogas-Soldevila et al., 2015). Other ingredients such as cornstarch, acetic acid, calcium carbon- ate and cellulose are present in the solution (Mogas-Soldevila et al., 2015). A consistent extrusion flow rate was achieved by applying a linear plunger pressure of 50mm/s and a maximum axial load of 75N after multiple stages of testing (Mogas-Soldevila et al., 2015). Deposited chitosan materials through additive manufacturing processes rival that of traditional polymers such as Nylon, ABS and PLA in tensile strength (Mogas-Soldevila et al., 2015). Further progress must be made in the flexibility and compression measures to begin completely replacing these materials. Glycerin plasticizers are being tested to

achieve these properties (Mogas-Soldevila et al., 2015).

A robotic arm and additive manufacturing technology were developed for this project. The platform works off of synchronized parameters such as speed, path, position and extrusion (Mogas-Soldevila et al., 2015; Tai et al., 2018). The six-axis robotic arm is protected in a glass container and has a customized 6-barrel extrusion head (Mogas-Soldevila et al., 2015; Tai et al., 2018). The print bed is 1m wide and utilizes fans for precise cooling and evaporation procedures (Mogas-Soldevila et al., 2015). Printing is not defined to a certain length or measure; this allows for larger assemblies and overcomes size constraints that limit most additive manufacturing technologies.

Drawing from further nature inspiration, the patterns and design choices of the pavilion take influence from leaf and dragonfly wing geometry (Mogas-Soldevila et al., 2015). Dragonfly wings are stiff and strong even with their light mass and thin profile; corrugation patterns achieve these qualities (Mogas-Soldevila et al., 2015). Dragonfly tensile strength and stability are subject to multiple factors including the hydration levels of chitin and proteins (Mogas-Soldevila et al., 2015). Leaves have a similar shape to dragonfly wings and face the most tension under their longer axis (Mogas-Soldevila et al., 2015). Parallel veins help to relieve this stress and stabilize the leaf when under force (Mogas-Soldevila et al., 2015). The additively manufactured sheets were modeled closely af- ter these natural inspirations to prioritize tensile strength and stress distribution (“Aguahoja”, n.d.; Ling, 2018; Mogas-Soldevila et al., 2015). Figure 3 demonstrates different construction patterns and structures.

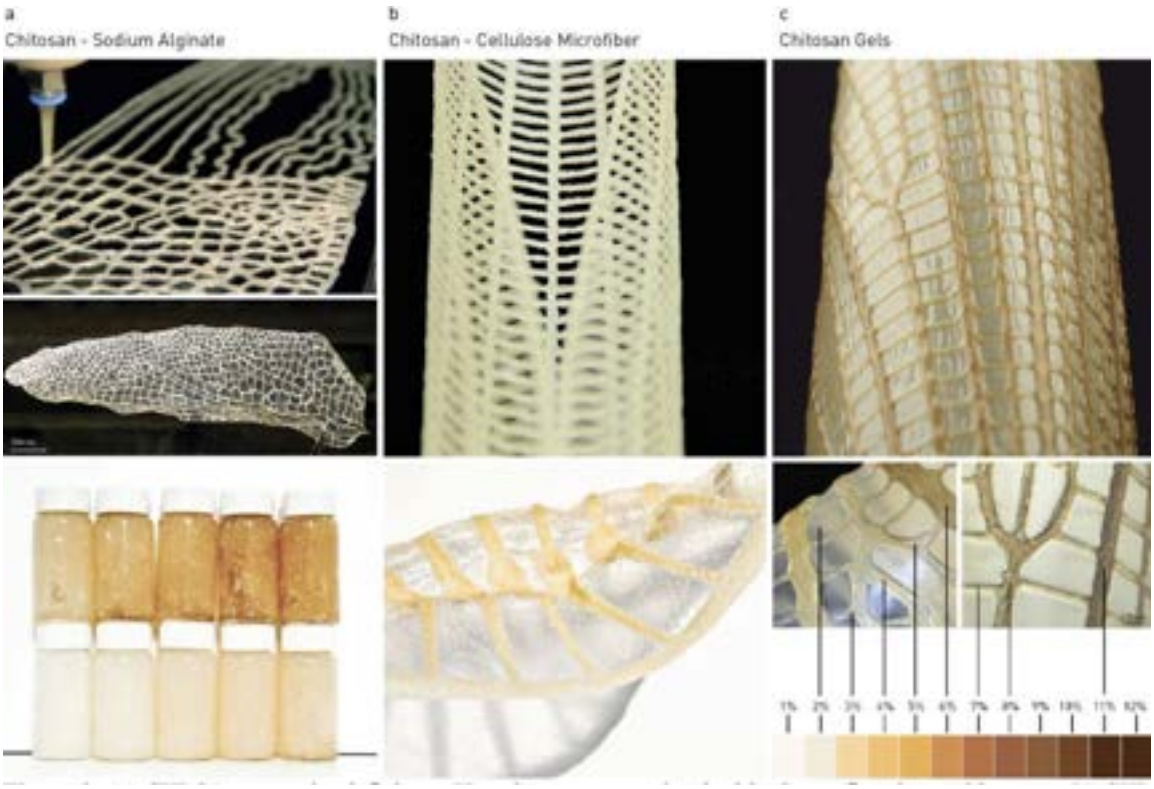

Figure 3: Chitosan-sodium alginate in dragonfly wing architecture, chitosan cellulose composite in grid and cyld- inrical structures and chitosan gels in leaf venation patterns
Accessed from: Mogas-Soldevila, Laia, and Neri Oxman. “Water-Based Engineering & Fabrication:Large-Scale Additive Manufacturing of Biomaterials.” MRS Proceedings 1800 (2015).

During the process of developing Aguahoja, scientists invented and coined an approach called Fabrication Infor- mation Modeling (FIM) (Duro-Royo et al., 2017). This process bridges the gap between digital design and CAD software to the physical fabrication of an object. Additionally, using real-time feedback through sensors, cameras and more, measures can be taken in response to complications during the manufacturing process (Duro-Royo et al., 2017). This model has three main components: structural design templating, robotic manufacturing templating and environmental performance templating (Duro-Royo et al., 2017).

Structural template maps are designed to determine the toolpath of the extrusion head (Duro-Royo et al., 2017). The principal structure is in the longitudinal direction and has a thick diameter (Duro-Royo et al., 2017). The sec- ondary structure/printing phase is a thinner and less concentrated network (Duro-Royo et al., 2017). This network helps to give the structure the shape and form of a wall. The direction, magnitude, diameter and concentrations of both the principal and secondary structures are engineered to obtain the desired shape, form, weight and aesthetics

(Duro-Royo et al., 2017; Ling, 2018).

To achieve these results, robotic manufacturing instructions are programmed and implemented (Duro-Royo et al., 2017; Ling, 2018; Tai et al., 2018). Pressure variation in the extrusion head determines the amount of accumulated material (Duro-Royo et al., 2017). Different material types/concentrations can be utilized for different stiffness gradients. Lastly, multiple phases and layers of printing on top of previous layers reinforce the structure (Duro- Royo et al., 2017; Tai et al., 2018). In combination with the position, speed and material instruction, these three variables are controlled to physically produce the previously virtual construction (Duro-Royo et al., 2017; Tai et al., 2018).

Environmental performance templating optimizes the structure for decay and biodegradability (Duro-Royo et al., 2017). Different techniques such as hydrogel deposition, evaporation control systems and hydration levels con- tribute to the biodegradation process (Duro-Royo et al., 2017; Mogas-Soldevila et al., 2015). The uncoated struc- ture will degrade and provide nutrients to the environment upon exposure to weather events and precipitation ("Aguahoja", n.d.; Duro-Royo et al., 2017).

Specific properties of the panels are targeted and engineered at different points in the fabrication process. Shape properties are accomplished by changing hydration rates of the extruded material and the toolpath (Mogas-Soldevila et al., 2015). The altering of layering strategies, stiffness, pressure and speed determine the mechanical properties (Ling, 2018; Mogas-Soldevila et al., 2015). Lastly, visuals such as transparency and color are realized by the type of material used and the chitosan concentration (Duro-Royo et al., 2017; Mogas-Soldevila et al., 2015).

Aguahoja is unique in its approach to programming assembly and decay directly into the lifespan and quality of a material (Ling, 2018; Mogas-Soldevila et al., 2015; Mogas-Soldevila et al., 2014). Common building materials become obsolete over time and eventually are left behind (Z˘ ujovic´ et al., 2022b). However, they take centuries to degrade and recycling processes are inefficient and expensive (Z˘ ujovic´ et al., 2022b). Instead, disassociation qualities are predefined and optimized for the specific constraints and uses of a specific product (Ling, 2018; Mogas-Soldevila et al., 2015). Additionally, Aguahoja is extremely customizable because of its additive manufac- turing design process.

Researchers suggest future work around the implementation of microorganisms (Duro-Royo et al., 2017). Bacterial cultures and small organisms can be integrated and embedded within the structure, along with necessary nutrients and collection devices, to create a living and productive environment (Duro-Royo et al., 2017). Microbes can work to perform tissue formation, biomineralization, microbial digestion, ambient sensing and produce biofuels (Duro-Royo et al., 2017). Researchers believe that microorganisms can be printed using the additive manufactur- ing process and technology (Duro-Royo et al., 2017).

The technology developed in Aguahoja is constrained to working in 2 dimensions ("Aguahoja", n.d.; Ling, 2018; Tai et al., 2018). Although multiple layers are utilized in the fabrication process, the methodology primarily fo- cuses on 2 dimensions (width and length). To add a third dimension of fabrication, topics of research such as structural stability, durability,

adhesion between layers and drying/dehydration timelines must be advanced. If these technologies are achieved, Aguahoja technology will become even more applicable to multi-dimensional and complex structures, not just leaf-like panels.

Aguahoja is a significant step towards more sustainable and natural building processes; it combines 3D printing technology with biodegradable materials to create physical, applicable structures (Ling, 2018). Furthermore, this research contributes many valuable technologies and concepts: load-bearing engineering in additive manufacturing of polymers, developments of and changes to a structure over time and the combination of skin-like and structural components and environmental responsiveness. Aguaghoja is a novel attempt and exploration of biocompatible life and working with nature to produce mutually beneficial architecture (for both humans and the environment). Biocompatible living is an inevitable and relevant topic considering the strain on resources and health issues, and the contributions of Aguahoja take society one step closer to sustainability.

Bacterial Cellulose Advancements

Cellulose is the most abundant biopolymer in nature (Arnardottir et al., 2022; Derme et al., 2016). Cellulose can be found in the cell walls of eukaryotic cells and the cell walls of certain fungi. Cellulose's mechanical properties, such as biodegradability, high water retention, tensile strength, thermal stability and hydrophilic nature make it a versatile material with wide-ranging applications (Derme et al., 2016). Nevertheless, cellulose is overlooked in the architecture industry because of its inconsistent and difficult production processes. Reliable fabrication tech- niques are not yet identified and subtract from the validity of cellulose as a biodegradable material for architecture (Arnardottir et al., 2022). As shown in Figure 4, most bacterial cellulose fabrication methods generate a thick mat that can be dried to form a sheet (Derme et al., 2016). These techniques are both limiting in their applications and do not harness the potential upsides and advantages of bacterial cellulose's unique properties. Therefore, it is important to develop flexible bio-fabrication methodologies to begin the integration process of cellulose.

Figure 4: Wet bacterial cellulose pellicle being removed from culture (2006). Microbial cellulose pellicle.JPG [photograph]. Wikimedia Commons. https://upload.wikimedia.org/wikipedia/commons/2/2f/Microbial cellulose pellicle.JPG

Biosynthesis is one of the emerging procedures that tackles this issue. Biosynthesis should be differentiated from biomimicry; biomimicry is the practice of imitating and drawing direct inspiration from nature whereas biosyn- thesis is the process of converting substrate to form a living, growing organism/material. Consequently, morpho- genetic properties can be engineered for specific purposes through biosynthesis.

Self-assembly in bacterial cellulose can be utilized to form desired geometric shapes. Certain bacteria produce large amounts of bacterial cellulose. Acetobacter Xylinum secretes bacterial cellulose as a part of its metabolism process (Derme et al., 2016). Therefore, starch, soy resin and polyvinyl alcohol are excellent substrates to sup- port bacterial cellulose fabrication because A. Xylinum grows on the surface of these natural fibers. In a study, scaffolding with these substrates were submerged or covered in A. Xylinum, resulting in the growth of a bacterial cellulose pellicle (Derme et al., 2016). In this way, bio-composites were formed. The structures/support systems utilized directly influence the shape of the final bio-synthesized product.

Additionally, mechanical properties such as stiffness and strength are augmented and

engineered during the drying and solidification process (Derme et al., 2016) Different rates and methods of calcification determine the structural properties of bacterial cellulose bio-composites (Arnardottir et al., 2022; Derme et al., 2016). Hydroxyapatite, chitosan, alginate and agarose catalyzed the calcification process.

In this study, two different scaffolding methods were used: permanent and biodegradable (Derme et al., 2016). Permanent scaffolding remains embedded in the material, providing constant stability and lasting form. Polymers such as polylactic acid were used for scaffolding and additive manufacturing technologies can be used to fabricate these structures (Derme et al., 2016). In contrast, biodegradable scaffolding dissolves over time, leaving a com- pletely organic product.

Containing boundaries were utilized in the bio-fabrication process (Derme et al., 2016). In this case, bacterial cellulose growth took on a role similar to that of material in a mold. However, the material grows on top of itself, adhering and expanding over time. The product is limited to a final shape by the boundary. After growth, the bacterial cellulose membranes can be removed from the containing structure (Derme et al., 2016).

The results of this study demonstrate that bacterial cellulose is moldable and subject to influence during its cultiva- tion stages (Derme et al., 2016). Sisal was found to be the substrate that grows bacterial cellulose most effectively (Derme et al., 2016). Lastly, bacterial cellulose's ability to grow on a predefined surface/shape was confirmed; the addition of oxygen during fermentation increased bacterial cellulose's tendencies to adhere and grow superficially (Derme et al., 2016).

One study based bacterial cellulose engineering and formation techniques on existing protocols to grow bacterial cellulose in Hestrin and Schamm's medium (HS) (Arnardottir et al., 2022). HS medium is a common mixture used to produce bacterial cellulose. In this study, Komagataeibacter Xylinus bacteria was used (Arnardottir et al., 2022). The two factors determining the thickness of bacterial cellulose growth are access to nutrients and oxygen.

After culturing K. Xylinus for 3 days, cellulase was removed from the medium (Arnardottir et al., 2022). Cellulase is an enzyme that breaks down cellulose formations to produce glucose. However, this is harmful to bacterial cellulose production and cellulase was removed through a washing process. By altering the space where bacterial cellulose grows, pellicles of different thicknesses were achieved (Arnardottir et al., 2022). Bonds between cellu- lose layers were formed, increasing its total thickness. In contrast, growth processes that did not utilize the same restrictions resulted in multiple thin layers of cellulose (Arnardottir et al., 2022).

In this same study, future work was proposed. Light and optical aspects can be programmed into E.coli through optogenetic plasmids (Arnardottir et al., 2022). These genes are light-sensitive. Bacteria carrying a certain version of the plasmid would change color via red fluorescent protein production when exposed to light (Arnardottir et al., 2022). In contrast, different versions of this gene suppressed red fluorescent protein production and would not change color in light. E.coli bacteria can be mixed in with bacterial cellulose-producing organisms (Arnardottir et al., 2022). Therefore, when the bacterial compound is exposed to light, visual changes will occur.

Fabrication techniques using a robotic arm were suggested in this study. One methodology employs cellulase to determine the form of bacterial cellulose (Arnardottir et al., 2022). A

robotically controlled syringe drips cellu- lase onto the surface of the pellicle, breaking down the cellulose structure (Arnardottir et al., 2022). In this way, weaker/less concentrated points in the cellulose formation are engineered through the addition of cellulase. The second method uses a suspended projector. The final 3D desired form is sliced into 2D layers. In this methodology, E.coli is mixed with the bacterial cellulose-producing organisms The projector illuminates the cellulose layer in certain spaces to alter the visual properties of the structure (Arnardottir et al., 2022). It is important to note that these technologies are compatible and can be combined to engineer form and color.

A prototype fermentation vessel will be used to produce bacterial cellulose layers. Through an automated Arduino process, the medium liquid level is raised to meet the height of the bacterial cellulose pellicle growth (Arnardottir et al., 2022). This encourages bacterial cellulose to grow in the vertical dimension (Arnardottir et al., 2022). The structure will have a syringe that deposits cellulose-degrading chemicals, a nutrient storage container and pumps to deliver nutrients (Arnardottir et al., 2022).

Significant concerns about the environmental effects of bacterial cellulose and other engineered polymers exist. Releasing engineered organisms in high and unusual concentrations into nature will lead to many unintended con- sequences and long-term effects (Arnardottir et al., 2022). Scientists are unclear on how wildlife, plants and other organisms will interact with these materials. Additionally, if living materials become contaminated during their fermentation, development or final stages, the structure can become compromised and damaged (Arnardottir et al., 2022). Further conscientious and comprehensive research must be conducted to examine and address both the immediate and long-term effects of integrating engineered biodegradable materials into natural settings. Possible solutions are specific post-production treatments, selective installation sites and techniques that dissuade wildlife interaction.

Cell-free synthetic biology is the term that refers to engineering and utilizing biological processes outside of a cell (Arnardottir et al., 2022). Activities like photosynthesis, protein synthesis and metabolic processes that occur inside of a cell can be performed outside of the cell through cell-free synthetic biology techniques (Arnardottir et al., 2022). Advancements in this field will enable the fabrication of gene networks, metabolic pathways and other complex systems to be embedded in materials without the use of entire cells and cell structure. These processes will increase the function and value of biologically sourced materials over traditional composites because of their potential to carry out additional operations. Furthermore, cell-free biology addresses issues related to releasing engineered organisms into the environment.

The use of cellulose and other living materials results in a prioritization of matter and material capabilities over the form or shape of the product (Derme et al., 2016). In contrast, common architectural processes value shape and aesthetics over the properties of the material. Furthermore, shape parameters and constraints are addressed over concerns of fabrication and material abilities. The application of cellulose allows for specific material properties and gradient condition engineering.

Chitosan Property Engineering

A study examined the effects of different proportions and concentrations of ingredients in a chitosan-based com- pound (Arnardottir et al., 2022; Mogas-Soldevila et al., 2015). Different amounts of water, chitosan, acetic acid, glycerin, cornstarch and calcium carbonate were experimented with (Arnardottir et al., 2022). In all of the differ- ent compounds, water was the main component, taking up around 80% (Arnardottir et al., 2022). Through simple tests, the mechanical and physical properties and aesthetics of the material were observed and analyzed (Arnardot- tir et al., 2022).

- Corn starch is used as a thickening agent that adds stiffness to the mixture (Arnardottir et al., 2022). Increases in corn starch result in increases in translucency and a whiter shade (Arnardottir et al., 2022). Furthermore, the cornstarch-to-water proportion must be carefully managed to ensure accurate physical transformations.
- Glycerine has strong effects on the flexibility of the compound and can override corn starch's effects on flexibility (Arnardottir et al., 2022).
- Calcium carbonate comes from powdered marble and limestone. Calcium carbonate increases the stiffness of the material and can result in a high stiffness-to-weight ratio (Arnardottir et al., 2022). Additionally, transparency is greatly affected by calcium carbonate (Arnardottir et al., 2022).
- A low proportion of chitosan (≤3%) results in viscous, transparent and flexible hydrogel (Arnardottir et al., 2022; Mogas-Soldevila et al., 2015). Viscous compounds are achieved by lowering the amount of chitosan. A medium proportion of chitosan (4-6%) correlates positively to strength and elasticity (Arnardottir et al., 2022). Finally, a chitosan preparation above 7% makes a stiffer, less flexible and opaque material (Arnar- dottir et al., 2022).

Further work and analysis of these materials in a 3D setting are necessary. The behavior and properties of these ma- terials may be changed when layered on top of each other. The addition of cellulose in the mixtures will decrease the plasticity index, making additive manufacturing processes more feasible (Arnardottir et al., 2022; Derme et al.,2016). However, cellulose will have other effects on the mechanical and visual properties of the composites that must be investigated.

Additive Manufacturing of Earthen Material Soil

Additive manufacturing has generally focused on advanced and chemically engineered materials (Ponce, 2019). 3D printing is not a sustainable process if harmful filaments and extrusion materials are used such as plastics and concrete (Mathur, 2016; Z˘ ujovic´ et al., 2022b). However, low-grade organic materials such as soil still remain a possibility. Soil is considered a less advanced building material and was commonly used for ancient structures and huts. The material still possesses many advantages for construction: structural makeup, diversity in appear- ance/aesthetics and ability to adapt to the environment.

Researchers developed an additive manufacturing method to "print soil" (Mitterberger &

Derme, 2019). Before beginning the process, a structure is built to contain the material that will be molded and formed; this structure is a mold of the desired form (Mitterberger & Derme, 2019). Soil composites are pressed into a thin layer into the interior of the structure by a human (Mitterberger & Derme, 2019). A human distributes the soil equally across the surface and then compresses it (Mitterberger & Derme, 2019). Next, binding agents that provide shape and stabil- ity and absorb water without eroding the structure, known as hydrogels (polysaccharide agarose with agaropectin), are deposited into the layer (Mitterberger & Derme, 2019). The hydrogels are sprayed onto the surface and concen- trated in structurally integral parts and where more stability is needed (Mitterberger & Derme, 2019). The earthen material structure is now ready for the next layer of soil and hydrogels (Mitterberger & Derme, 2019). This pro- cess is continued until the original boundary structure is completely full (Mitterberger & Derme, 2019). Additional treatments are performed to ensure stability under both tension and compression (Mitterberger & Derme, 2019). Lastly, the boundary structure is excavated, leaving a self-supporting result (Mitterberger & Derme, 2019).

It is important to recognize the limitations of this process. One significant drawback of this technology is that it is not completely automated; six-axis, spring-loaded robotic arms have been utilized to optimize soil compression and deposition (Mitterberger & Derme, 2019). More progress must be made before this process can be consid- ered completely roboticized. In addition, the process requires a supporting boundary structure for fabrication and printing to take place (Mitterberger & Derme, 2019). This is an inconvenient requirement that limits the range of applications of this technology. Lastly, this process struggles to create hollow structures. The soil deposition process is not able to create concave space, and therefore, the end product cannot have enclosed interior spaces (Mitterberger & Derme, 2019).

An important place for advancement in this technology is the strengthening of hydrogel functions. If the hydrogel is very effective at absorbing water, the structure will be able to withstand harsh weather conditions. Furthermore, the stability of the shape will improve; another possibility for enhanced strength is the addition of internal supports.

Clay Composites

In 2018, a 35 square meter house called Gaia was 3D printed (Jordahn, 2019; Pak & Orhon, 2019). The house has a circular shape with a radius of 3.3 meters and a height of 3 meters (Jordahn, 2019; Pak & Orhon, 2019) The walls of the house were 3D printed and contained clay, silt, sand, straw husk, rice and lime (Pak & Orhon, 2019) This combination of natural materials formed a mud-like mixture that decomposes back into soil if not maintained (Jor- dahn, 2019). The materials were sourced off-site and waste materials from rice production sites such as chopped straw and rice husks were also used (Jordahn, 2019). A similar clay composite structure manufactured by the same company is shown in Figure 5.

Figure 5: TECLA house: 3D printed residential structure made of clay
Milano, A. (2021). Eco-sustainable 3D printed house ”Tecla”.jpg [photograph]. Wikimedia Commons. https://upload.wikimedia.org/wikipedia/commons/b/bb/Eco-sustainable 3D printed house %22Tecla%22.jpg

A 3D printing crane was suspended in the air by three supports and manufactured the structure layer by layer (Jordahn, 2019). The robot has three dimensions of motion and moves in a hexagonal grid system (Pak & Orhon, 2019). Cavities, as shown in Figure 6, in the walls were left to be filled with rice husk, a natural insulator (Jordahn, 2019). Internal timber supports were installed in order to ensure stability and support the roof (Es-sebyty et al., 2022; Jordahn, 2019). A timber roof was added, as well as a door and windows (Pak & Orhon, 2019). Rice husks were also used as plaster for the interior wall and spread on top of the roof for insulation purposes (Jordahn, 2019).

Figure 6: 3D printed clay composite wall structure with internal cavities
Milano, A. (2021). 3D-printer arm for semi-automated construction of sustainable houses.jpg [photograph]. Wikimedia Commons. https://upload.wikimedia.org/wikipedia/commons/b/b2/3D-printer arm for semi- automated construction of sustainable houses.jpg

The house only took ten days to complete and the mud mixture required $1,140 to produce (Jordahn, 2019). This project has the advantage of extreme efficiency and cost-effective production processes (Pak & Orhon, 2019). Fur- thermore, its use of agricultural waste to fabricate the building helps to tackle issues of waste management in the agricultural sector (Jordahn, 2019). Its insulation capabilities lower its cost of maintenance as it will not require significant heating or cooling (Jordahn, 2019).

The developers of this project hypothesize that waste materials from other building sites can be processed into an extrudable paste (Jordahn, 2019). Following the blueprint and proof of concept that GAIA has achieved, this mixture can be additively manufactured into a house (Jordahn, 2019). This concept can contribute to solving waste/demolition management efforts; additional research must be performed in this space to improve its effi- ciency.

A separate study analyzed the stability of the GAIA house and identified possible solutions (Es-sebyty et al., 2022). The GAIA house is unique in that it does not use beams or supports in the

walls (Jordahn, 2019). Although there are wooden beams inside of the house, these are used to support the roof, not the walls/exterior. This study suggests two possible solutions: a house without reinforcement and a house with reinforcement (Es-sebyty et al., 2022).

The house without reinforcement will be designed with two walls (Es-sebyty et al., 2022). Columns and beams can be added to support the weight of stacked levels of the house (Es-sebyty et al., 2022). The other solution is built with only one wall but requires scaffolding and supports embedded in the walls (Es-sebyty et al., 2022). After undergoing multiple computer simulations, it was found that both systems conform to anti-earthquake standards for earthen construction (Es-sebyty et al., 2022). However, concerns about the degradation and deterioration of materials over time and exposure to weather still persist. Furthermore, issues of fracturing during the drying pro- cess remain.

3.7 Additive Manufacturing of Concrete

Significant research has been performed in the additive manufacturing of concrete (Bos et al., 2016; Saleh Abd Elfatah, 2019). Concrete and similar materials are limited in their ability to biodegrade (Bos et al., 2016; Zˇ ujovic´ et al., 2022b). However, they are one of the most advanced materials in additive manufacturing for architecture. Two case studies and proof of concepts will be presented. A common technique for constructing walls via the extrusion of concrete is shown in Figure 7.

Figure 7: Additive manufacturing of concrete wall via crane (2022) 3D printed wall.jpg[photograph]. Wikimedia Commons. https://upload.wikimedia.org/wikipedia/commons/f/ff/3D printed wall.jpg

In 2016, the Apis Cor Concrete House was printed by the Apis Cor Company (Pak & Orhon,

2019). The house is entirely printed of concrete and fiberglass was installed in between gaps to reinforce the shape and provide scaf- folding during the drying process (Pak & Orhon, 2019). The robotic arm was fixed in the center of the house. The installation of the robot took 30 minutes and the entire printing of the house took 24 hours (Pak & Orhon, 2019). Doors and windows were also installed (Pak & Orhon, 2019). This project excels for its rapid speed of production. The manufacturing of the house was around $10,000 (Pak & Orhon, 2019).

The BatiPrint Company printed a larger 95 square meter house in 2018 (Pak & Orhon, 2019). The building has 5 rooms and took around $200,000 to produce. Concrete and polymeric foam were used as building materials (poly- meric foam is a foam containing multiple polymers) (Mosse & Bassereau, 2022; Pak & Orhon, 2019). Polymeric foam and concrete were printed from the robotic arm. Doors and windows were also installed (Pak & Orhon, 2019).

Although limited in its sustainability, there are still many advantages to using additive manufacturing in the con- struction industry: it is safer than traditional techniques, construction time is reduced, cost is lower, more opportu- nities for customization and design are available, less waste is produced and more (Ponce, 2019; Sakin & Kiroglu, 2017; Saleh Abd Elfatah, 2019).

The additive manufacturing of concrete is limited to smaller-scale structures (Bos et al., 2016; Saleh Abd Elfatah, 2019). Multi-story buildings are more difficult to manufacture as 3D printed concrete struggles under the weight of other layered levels (Ponce, 2019; Sakin & Kiroglu, 2017). However, the addition of scaffolding and supporting structures provides stability and helps to scale the building process. Many different methodologies for achieving structural integrity exist (Es-sebyty et al., 2022; Sakin & Kiroglu, 2017). In certain cases, post-tensioning pre- stressed bars are fed into gaps and holes in the structure. Glass fiber mesh can be installed between layers. Steel frames can be printed around.

One study presented and developed technology for clay extrusion through additive manufacturing for lattice struc- tures (Birol et al., 2022). A product titled “Polybrick” was achieved by 3D printing clay composites and other materials (Birol et al., 2022). This brick is porous and contains bridge contours to increase the strength and compressive strength (Birol et al., 2022). A comprehensive workflow was presented that ultimately generates

load-responsive and material-efficient brick modules (Birol et al., 2022). These brick modules can be stacked and combined together to form larger walls and structures (Birol et al., 2022). Although the weight-bearing capabili- ties of these bricks were promising, additional research must be conducted to ensure their stability and consistency over time and exposure to weather.

The design and planning process to create a "polybrick" can be time-consuming and reliant on user input (Birol et al., 2022). Machine learning and automated processes would be extremely beneficial for the production pro- cess (Birol et al., 2022). As a result, the properties of bricks could be individually engineered depending on their final role and position in the complete assembled structure (Birol et al., 2022). Automated design would also in- crease the amount that additional factors such as heat transfer, water flow and airflow can influence the fabrication method (Birol et al., 2022). Nevertheless, other applications of the additive manufacturing of clay/concrete to produce bricks, rather than complete walls and assemblies, exist and merit further exploration.

Similarly, applications for the additive manufacturing of concrete are not limited to the manufacturing of a structure (Ponce, 2019). Off-site uses exist; technologies could be used as a substitute for concrete mixers. Additionally, they can be used in the prefab industry to produce smaller parts of a structure off-site with efficiency and reliability. There is significant potential in this space to incorporate additive manufacturing technologies in a factory setting to produce specific, individual parts. Additive manufacturing technology can be developed and customized in detail to consistently construct one part; this limits concerns about stability and durability throughout an entire structure because printing patterns and methods will be optimized for one purpose.

The ultimate solution would be to develop a concrete printing process and concrete mixture that is capable of sus- taining its own weight, without additional support. Fibers such as glass, basalt, and carbon fibers have been mixed with concrete to produce such a compound (Bos et al., 2016). Further research must be conducted in this space to ensure that layers of concrete adhere and bond to each other and that uniform distribution is achieved without clogging the extrusion head.

Another challenge is then presented in how the additive manufacturing technology can reach the top of structures to continue printing. Further research and concepts to develop large-scale cranes or robots that can travel on the vertical axis to construct a tall structure are needed.

Lastly, shrinkage and creep in layered concrete must be explored. Small changes and deformations in the printed concrete lead to fractures and compromised layers. These issues could result in catastrophic consequences, espe- cially in the base layers of large-scale structures. Tactics and technologies to minimize these complications must be invented and refined.

Additional Research Foam for Construction

One study took a unique approach to biodegradable materials and investigated paper-based foam as a sustainable building material through 3D printing (Mosse & Bassereau, 2022). Paper is one of the top waste materials in the entire world (US EPA, 2017). However, paper is not always recycled or repurposed which presents a need for new uses of discarded paper (US EPA, 2017). By combining crushed black and white paper, a foaming agent, starch- based glue and water, a biodegradable and sustainable foam is achieved (Mosse & Bassereau, 2022). The paper must be

crushed to a granularity smaller than 1mm, creating a thin powder-like substance (Mosse & Bassereau, 2022). Many different concentrations of and types of adhesive and foaming agents (Mosse & Bassereau, 2022). The most successful composite contained 320g of water, 70g of paper homogenate, 20g of a lightweight concrete foaming agent (Genfil) and 20g of starch adhesive (Mosse & Bassereau, 2022). The final solution is achieved after different spraying, shredding, mixing and blending steps (Mosse & Bassereau, 2022).

Foam was inserted between two sheets of paper and produced hardened plates of different thicknesses (Mosse & Bassereau, 2022). Additionally, different paper types such as magazine pages, drawing paper, wrapping paper and more were experimented with (Mosse & Bassereau, 2022). Color and visuals could be engineered by adding vegetable dyes during the foam production process (Mosse & Bassereau, 2022). Textural effects were obtained through laser-current, embossing, engraving and other surface treatments (Mosse & Bassereau, 2022)

3D printing this material opens up new possibilities for fabricating complex geometries that can not be achieved through a mold (Mosse & Bassereau, 2022). Furthermore, functional grading can be realized and specific proper- ties of the foam are more adjustable (Mosse & Bassereau, 2022). During the 3D printing experiments, flow issues were immediately encountered; the paper fibers would remain in the syringe and become clogged while water was extruded (Mosse & Bassereau, 2022). As a result, the extrusion head was changed to an air-pressure piston-driven 150ml syringe; a much smoother and more consistent flow was achieved (Mosse & Bassereau, 2022). After print- ing, the structures were subject to a 30% volume decrease as a result of water evaporation (Mosse & Bassereau, 2022). Although adhesion between layers is strong, these structures are more fragile and brittle than the results of other production techniques.

Thinner paper and methods to achieve homogeneity in the solution must be explored to ensure a reliable extrusion. Additionally, production techniques and timelines for foam must be altered specifically for the additive manufac- turing processes. Lastly, the fragility and shrinking of structures must be addressed. Shrinking (especially at a high rate) presents significant challenges because the final product can be unpredictable or inconsistent. Biodegradable foam most likely does not have applications as a supportive building material; instead, it can be utilized for insula- tion, interior design and non-weight-bearing components.

Applications in Packaging

Other applications of the additive manufacturing of renewable materials lie in the packaging industry (Zeidler et al., 2018a). Researchers have sourced natural materials such as miscanthus, wood flour, seashells, rice husk and more for additive manufacturing processes (Zeidler et al., 2018a). To prepare these materials for the binder jetting extrusion process, they are crushed into a fine powder that can be pushed through the nozzle of the machine (Zeidler et al., 2018a).

An important aspect of this process is the selection of the binder material. For the product of additive manufactur- ing to be truly renewable, the binder material must be non-toxic and decomposable as well (Zeidler et al., 2018a). These requirements are not fulfilled by normal 3D printing binders (Zeidler et al., 2018a). In this study, lignin sulfonate, sodium silicate (water glass) and polyvinyl alcohol were tested (Zeidler et al., 2018a).

The best results in terms of compression strength were achieved by epoxy resin infiltration along with steering and acrylic resin (Zeidler et al., 2018a). It is important to note that this study solely focuses on the applications of this technology in the packaging industry. The experiment was conducted with the goal of low-cost, biodegrad- able packaging. Therefore, many of the methods used are not suitable for scaling or utilization in the larger-scale architecture industry (Zeidler et al., 2018a). Nevertheless, lightweight materials with mechanical damping and low thermal conductivity qualities were produced. These have possible applications as insulation or internal non-weight-bearing appliances and decorations. These material and binder combinations are most suitable for the fabrication of individual, unique and complex small components/parts.

Discussion

The adoption of 3D printing in the architecture industry proposes other unintended issues and consequences. Ad- ditive manufacturing will replace manual labor, resulting in decreased job

opportunities. Smaller construction companies will not be able to compete with larger corporations with greater access to developing technologies. Additionally, the current construction industry will be doubtful and speculative about incorporating additive man- ufacturing. These new technologies must overcome significant social backlash and opposition. Therefore, the integration of 3D printing must be a thoughtful and sympathetic process.

Certain practices and guidelines must be adhered to in order to ensure a successful transition. Industry experts and leaders must increase their collaboration with academia and institutions; this will promote the production of more suitable and practical products. Large capital investments must be directed to this developing field. Similarly, out- standing projects with foci on sustainability and clean processes must be rewarded to encourage entrepreneurship. Governments and powerful organizations must create and implement laws for additive manufacturing practices; these regulations must cover topics of sustainability, economic impacts, safety and ethical issues such as job loss and turnover. Lastly, uncompromising commitments to safety must guide all decisions.

Hydrogels are a critical component of many additive biodegradable construction materials, especially earthen ma- terials (Almpani-Lekka et al., 2021; Jordahn, 2019; Mitterberger & Derme, 2019; Mogas-Soldevila et al., 2015; Tai et al., 2018). The development of effective hydrogels that do not debilitate over time is necessary to fabricate sustainable and durable structures. Furthermore, practices to integrate hydrogels directly into the manufacturing process or techniques for applying exterior layers of hydrogels must be cultivated.

A theme across the majority of additive manufacturing processes is the desideratum for structural supports and scaffolding (Derme et al., 2016; Es-sebyty et al., 2022; Mitterberger & Derme, 2019; Mogas-Soldevila et al., 2015). Many biodegradable materials, as well as traditional composites such as concrete, are not capable of sup- porting their own weight when 3D printed. In addition, internal lattices provide the materials with form and offer an initial structure to fabricate around. Versatile techniques for internal support must be established. Moreover, support structures made out of biodegradable or eco-friendly materials should be investigated to enhance the ab- solute sustainability of assemblies. Optimistically, decomposable materials that can support themselves will be engineered.

Similarly, the structural integrity and longevity of additively manufactured biodegradable material constructions require research and development. Although multiple structures have proven to be resistant to compression, ten- sion and other forms of stress, further advancements must be made (Es-sebyty et al., 2022; Mogas-Soldevila et al., 2015; Pak & Orhon, 2019; Saporta & Clark, 2016; Zeidler et al., 2018b). For naturally-sourced constructions and additive manufacturing to gain validity in the architecture industries, they must excel in safety measures and tests. Otherwise, their liabilities of collapse or decay will quash and retract from their advantages and benefits. Most simulations and assessments have taken place in a protected lab setting. However, the settings of potential real-world applications are not secure or closely monitored. It is important to examine the effects of other factors such as time, weather, usage and nature interaction will play in permanence and deterioration. Mycelium and bac- terial cellulose production processes need standardization and refinement. Many fabrication methodologies exist, all with different benefits (“6 ways mushrooms can save the world — Paul Stamets”, 2008; Derme et al., 2016; Ho et al., 2023a; Karimjee, 2014; Vallas & Courard, 2017). However, to encourage commercialization and application in architectural

fields, more consistent techniques must be identified. Different procedures should be employed depending on the parameters and priorities for the final product (strength, aesthetics, scale). Advantages and fertile aspects of processes should be combined and balanced together to create more polished solutions.

Additionally, as these materials are made of or produced by living organisms and biology, the environmental ef- fects must be studied to a greater extent than that of synthetic substances (Arnardottir et al., 2022; Derme et al., 2016; Ling, 2018). Introducing large concentrations of new biological materials will likely result in unintended consequences and changes to the existing ecosystem. Therefore, conscientious and diligent research must be con- ducted before installation and integration.

Although additive manufacturing and biodegradable materials are individually relatively established and accepted in the architecture industry, the combination of these concepts is still considered experimental and boundary- defying (Almpani-Lekka et al., 2021; Bondre, n.d.; de Leo´n et al., 2023; Karimjee, 2014). To achieve validity, additional research and experimentation must be conducted and promoted. Large-scale and successful proof of concepts and constructions must be publicized to push the intersection of these fields into the mainstream. The ad- ditive manufacturing of biodegradable materials requires significant progress and advancements before it is ready for commercialization and widespread applications; nevertheless, the promotional and informational campaign must begin now considering the rapid rate at which these technologies are developing.

Conclusion

Biodegradable material construction through additive manufacturing methodologies is an outstanding architectural innovation that advances society toward sustainable practices; additive manufacturing processes are energy and material-efficient and naturally-sourced materials are benevolent alternatives to divisive and harmful industry stan- dards. Additive manufacturing is a solution to time-consuming and complicated biodegradable material installation procedures. Moreover, harmful and unsustainable synthetic filaments can be replaced by organic and naturally-sourced compounds. Through collaboration and experimentation, safe, eco-friendly and functional constructions can be achieved. The author of this paper hopes to convince readers of the relevance and potential of this field and encourage values of sustainability and safety to determine future architectural research.

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Period Poverty and its Worldwide Effect By Sreejani Sinha

Abstract

Period poverty is a worldwide phenomenon affecting millions of people every year. Period poverty is the lack of access to proper menstrual sanitation, education, and hygiene, prevalent all over the world. Most women in poverty suffer from period poverty, but the two are not synonymous; poverty refers to a lack of financial resources in general. Period poverty restricts women from living their daily lives by putting obstacles on their educational and professional lives. The issues period poverty include accessibility, affordability, and cultural stigma, but countries have been making increasing efforts to deal with the issue to help uplift women. With increasing efforts and proper protocol in regards to period poverty, governments and societies can help women in every aspect of their lives. The best solution to period poverty is an increased effort from governments and international organizations to increase the amount of menstrual products and infrastructure made, to make it more affordable, and provide proper and widespread education regarding menstruation.

Introduction

Period poverty is defined "as the lack of access to safe and hygienic menstrual products during monthly periods and inaccessibility to basic sanitation services or facilities as well as menstrual hygiene education" (Jaafar et al. 2) and unfortunately it affects millions of people yearly; in fact, "[t]wo-thirds of the 16.9 million low-income women in the US could not afford menstrual products … half of this needing to choose between menstrual products and food" in 2022, according to the *Journal of Global Health* (Michel et. al 1). Period poverty goes beyond affordability, however, including mental health problems, effects on the environment, and cultural stereotypes (Rohatgi and Dash 1). For many women in poverty (or women with a general lack of financial resources), there is little to no infrastructure regarding menstruation, including clean public toilets, and access to water, to name a few. This affects these women's education and schooling, as this lack of infrastructure stops women from living their normal lives, which stops them from gaining further education and getting jobs. When women can't properly clean themselves or stop themselves from leakage, they often don't feel dignified enough to do their normal day-to-day activities. Additionally, the cultural and social stigma against periods in certain societal standards also forces women to stay at home and restrict them further. For example, in Christianity since blood is deemed as impure, throughout history women on their period were heavily discouraged from praying (Ott 5). Additionally, in light of the COVID-19 pandemic, these issues of affordability, as well as mental and cultural issues have only been further exacerbated. During the pandemic, according to Pace University, many governments have made it so only essential businesses can stay open, but businesses distributing and creating sanitary products don't fall under this category further building the divide regarding period poverty (Crawford 1574). The many social, cultural, and professional restrictions that period poverty puts on women in poverty, culturally, and mentally, have ripple effects all over the

world economically and socially. The main issues that create and aggravate period poverty are affordability and accessibility. Period products and infrastructure are very expensive for those already in poverty and sometimes buying menstrual products can mean not paying for other needs, like food. Similarly, for women in impoverished communities, the number of menstrual products available is limited due to limited production and lack of prioritization. Despite all these problems regarding period poverty, some countries are applying reforms to help alleviate period poverty.

Affordability

A large aspect of period poverty is affordability; as stated before, women in poverty largely can't afford period products and proper infrastructure due to their prices and high taxes. In fact, tax on menstrual products in the US ranged from 4.7% to 10% in 2019 (Michel et. al 1). Women in these situations often have to choose between basic needs, like food and hygiene, and period products. Governments oftentimes don't view period poverty as a legitimate problem in need of addressing, causing prices of these products to stay the same or even rise. In the U.S. and many other countries period products are not seen as a necessity and therefore are taxed like regular-sales goods. Unfortunately, these high prices are only made worse as more and more women become unemployed during the pandemic. Researchers from the *National Library of Medicine* writes "10% of girls in the United Kingdom have been unable to purchase menstrual products, … and 19% have switched to less appropriate products because of high costs" in 2022 (Jaafar et al. 1). Similarly in the U.S, "[i]t is estimated that 16.9 million menstruating women in the United States live in poverty, two-thirds of which are low-income and food-insecure women who cannot afford basic menstrual products such as pads, tampons, and menstrual products" (Sacca et al. 1). These economic struggles are not only sources of shame for these women, but also unhealthy, as low-quality period products have been known to cause health problems because of their increased use of chemicals and unnatural materials (Nicole 1). This means on top of already lacking medical resources, impoverished women risk getting hurt at higher rates and suffer more from period poverty.

Oftentimes, women in poverty are almost punished by society for simply not having the resources for better goods. Unfortunately, impoverished women all over the world experience this kind of disparities, and this lack of products further exacerbates the educational and professional struggle these women face, as "[t]he lack of access to menstrual products can prevent menstruators from leaving their homes, limiting their ability to work" (Chicaiza 1), which further affects the economic and financial lives of these women. Ultimately, for millions of women in poverty, affording period products is a financial struggle, which leads these women undignified and unable to complete daily tasks like going to school or going to work. In rural and impoverished communities, women often have to leave school early as it is due to societal and economic pressures, but due to period poverty, these women are forced to lessen the education they receive because of the expenses that come with simply having a period. This is also concerning considering that women are more economically self-sufficient, they are more likely

to invest within their families, benefiting local economies for decades to come (OECD 2). All in all, for many women, having a period is a restriction and barrier in everyday life because of the lack of affordability when it comes to period products.

Accessibility

Aside from the lack of affordability with period products, like menstrual pads and tampons, basic accessibility to such products and infrastructure are out of reach for many impoverished women. Many governments obviously don't view period products as a necessity, as seen during the COVID-19 pandemic, when period product factories closed, and the production of sanitary products also halted. The researchers from *National Library of Medicine* reported that "73% … agreed that the pandemic restricted access to menstrual supplies due to acute shortages in production and dismantled supply chains" (Rohatgi et al. 1). This decrease in production on top of the existing expense of period products, obviously further exacerbates period poverty. The demand for sanitary products is extremely high and when supply chains cannot meet those demands, and governments don't treat these products as a priority, millions of low-income women are left without adequate materials needed during their period. This means millions of women are barred from living their everyday lives and left undignified. Aside from the lack of accessibility regarding period products, accessibility to hygiene is also a major issue for many women in marginalized communities. For women in refugee camps or homeless shelters, water is close to inaccessible. For refugee households there are "low levels of access to waste disposal facilities (64%) and sanitation privacy (63%), and very low access to basic sanitation (30%)" according to the *International Journal for Equity in Health* (Calderón-Villarreal et al. 1). This is extremely concerning considering practicing cleanliness during one's period can help make people feel comfortable and prevent infections (CDC 1). Aside from the effects on self-confidence, when women don't have the basic infrastructure to practice good hygiene they are at risk of hurting themselves medically, which can further add to their ongoing financial struggles. The lack of access, both in regards to hygiene and products, brings back prior points made of period poverty affecting women educationally and professionally; by not being able to maintain their hygiene they are not only left feeling undignified but don't find it appropriate to attend school and work, affecting themselves and their families economically. In conclusion, the lack of infrastructure in place in regard to the production of sanitary products as well as basic hygiene put obstacles in place for low-income women to succeed and live normal lives.

For many women and girls, the cultural and social stigma in many impoverished communities also stops low-income women from achieving success. In already misogynic societies, the existence of periods serves as a reason to further ostracize and restrict women. When on their menstrual cycle women are often considered "'dirty, disgusting, defiling"' and "'out of control'' (by communities and even family) according to Elizabeth Grosz, a professor at Duke University (Oslen et al. 1). It is clear that in many developing countries, a woman's natural bodily processes are considered something to be ashamed of and hidden, affecting people's

self-confidence and dignity. These misconceptions, or social stigmas, about menstruation are further perpetuated by religion and traditional beliefs as well. These social stigmas often isolate young girls from going to school and going to places of worship. In addition to these taboos portraying periods as unhygienic, in many societies, a woman's first menstrual period is a sign that she is prepared for childbirth and marriage (Wibowo 1). This is especially alarming considering the average age for young girls to start their period is between 10 and 16 years old (Lacroix et al. 1). While women in poverty often have to miss out on their education because of lack of affordability and accessibility, these beliefs on maturity and menstruation completely stop women from accessing secondary education. The ethical issues with this are extremely evident, as these young girls are often married off against their will; these girls also lose their potential for financial success. Sadly, these stigmas and stereotypes about periods stop lawmakers from achieving real change with programs and legislation aimed to help uplift period poverty. Researchers from Columbia University clarify that "[p]olicy-makers seem constrained by the very stigma they seek to tackle, resulting in hesitancy and missed opportunities" (Olson et al. 1). This means that there is little governments can do to change the social and cultural ideas and myths surrounding periods for these rural and generally uneducated communities, which means more grassroots efforts are necessary to undo and unlearn these ideas. In these impoverished societies, stigmas and taboos are created because of the lack of education about menstruation and menstrual health for all genders. In conclusion, the stigmatization around menstruation is detrimental to young girls' self-confidence and economic freedom.

Existing Efforts

Although in certain aspects of period poverty, such as social stigma and misconceptions are difficult to legally regulate, there are actions governments can take that can help these women and young girls in terms of affordability and accessibility; some governments have already slowly started taking action to help disadvantaged communities and women in poverty when it comes to menstruation. New legislations and programs implemented across the world reveal how governing bodies could increase affordability, and accessibility, and reduce stigma. The most prominent legislation passed in recent times has been Scotland's Period Products Bill, making period products free for all (Diamond 1). This decision is monumental as it solves the issues of accessibility and affordability, helping Scottish women professionally and educationally, thus financially and economically. Although Scotland is so far the only country to do this, many countries are focusing on distributing more tampons and pads or are making them less expensive. For example, Mexico, Britain, and Namibia are only some of the countries that have alleviated the "tampon tax" (sales tax on menstrual products) (Baptista 1). More countries are putting in efforts to help women gain access to period products than ever before. If these efforts continue, millions of women will be uplifted and face fewer obstacles in their everyday lives.

Additionally, countries have started to distribute tampons and pads at schools to help students, which allows young girls to easily access cheap menstrual products, something they might not receive in their homes. In addition, the *World Bank* suggests subsidizing period

product manufacturers, to not only help with production but to encourage local manufacturers (World Bank 1). This would lessen struggles regarding the supply chain of period products, which would largely solve the problems regarding the accessibility and availability of these products. If every local manufacturer near impoverished communities were provided with subsidies, these communities would have more places to buy affordable products as well. Other ways to help solve period products are through government programs as government programs in developing countries, like the Rural Water, Sanitation and Hygiene for Human Capital Development Project in Bangladesh and Scaling-Up Water Supply, Sanitation and Hygiene Project in Lao, which aim to help the disadvantaged women acquire sanitary products and be able to stay discrete during the menstrual cycle. Through more programs directly aimed at period poverty, developing countries can help uplift women, which can help boost household income and education, and simply allow more people to be involved within society.

These prior efforts specifically deal with accessibility and affordability, but education can also be vital to help decrease period poverty. Increased education for all genders allows people to be more healthy and practice healthy habits during their period, know when something is abnormal, and decrease stigma in communities (Jaafar et al. 1). Examples of such initiatives are seen with "the Always Keeping Girls in School Program in South Africa which has been running for more than 10 years and has helped girls…focus on their education" (Brennan 1). The most positive implication of having these legislations and programs is the positive impact it has on education. Removing barriers in the realm of period poverty helps the development of young girls in marginalized and disadvantaged communities, as it allows them to access secondary and higher education, which eventually helps countries get more skilled manpower. Uplifting women is so important because women are known to contribute and invest more in their families and communities, so when governments uplift women they are uplifting entire communities and families which eventually helps national economies. In short, by implementing the correct legislation and programs, governments can uplift women in poverty and in turn positively impact the economy of communities and nations.

Conclusion

Period poverty is an extremely prevalent issue affecting millions of women worldwide; the issue of period poverty has been created by the lack of affordability and accessibility to proper products and infrastructure needed to stay healthy and dignified during menstruation (like proper bathrooms, pads, tampons, etc). The restrictions that come with period poverty have been proven to hurt not only women but entire communities and even countries, by restricting women from growing educationally and professionally. Such restrictions also stem from cultural myths associated with menstruation on top of the lack of afforability and accessibility. Period poverty has been proven to halt growth among already impoverished communities, but fortunately, can be properly dealt with through government and personal efforts by people in communities. Government efforts in Afro-Eurasia to improve production of period products and make products more affordable have shown to alleviate period poverty in impoverished communities. However,

aside from government efforts on the issue, individuals can also help solve this problem within their local communities. It can be done through simple product donations and raising attention to this issue. All in all, even though period poverty is an extremely multifaceted issue that needs great attention to be properly addressed, with proper protocol and meaningful legislation and efforts, institutions can help uplift women and change the trajectory of worldwide growth and prosperity.

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The Impact of Gender on Student Academic Achievement By Ellie Koff

Abstract

Male and female students exhibit differences in academic performance globally, where females tend to perform better in English sections of standardized tests, while male students demonstrate a higher understanding in math sections. Social influences and expectations of females and males contribute to creating a self-image that is linked to greater success in different subjects in schools. It is important to understand why females tend to have better success in English subjects and males in math as it may help to explain certain gender gaps in the workforce. The following research will respond to the question of gender being a predictor of students' success in particular subjects. This paper aims to consider different types of evidence and reasoning to conclude this topic by analyzing standardized test scores and understanding students' natural inclinations towards math and English subjects through the works of psychologists, and other researchers' experiments from 2017-2018.

Introduction

Gender can be defined as the way an individual chooses to express themselves through feminine or masculine traits, which is often identified as gender expression (Boskey, 2022). Expressing gender in either feminine or masculine ways can be displayed through clothing, appearance, language, speech, or certain behaviors (Boskey, 2022). Historically in America, girls have been taught how to act, speak, and behave in school, while boys are taught to be brave, strong, and emotionally tough. Education has been used as a demonstration of power through both gender and race for centuries. In America, female students were unable to attend school due to their gender. This early history of gender exclusion in education gives a foundation for the social position taught to many females in American society (Gershon, 2019). Before the year 2000, gender and sex were used interchangeably; more recently that terminology has changed. Gender is now viewed as a social construction that allows people to express themselves in whatever way they deem fit.

Girls are expected to wear dresses and skirts and act like ladies through a strong emphasis on teaching young girls the importance of how they present themselves to society. Boys are encouraged to play rough and show no emotion (Hogenboom, 2022). This idea in recent generations has sparked controversy as many young girls and boys are opposing these traditional roles and choosing to express themselves in their own ways and to their own desires (Baker, 2023). The social learning theory psychologist, Albert Bandera found that learning happens through observation, imitation, and modeling, as kids are continuously learning more about themselves and the world around them (Mcleod, 2023). Most of this learning occurs in the walls of school where at least six hours of their day is spent. Through these experiences in school, kids can form their own opinions and learn more about themselves, particularly how they choose to express their gender.

Most individuals know what gender they identify with early on, but as they mature and develop, their gender expression may change (Lichtenstein, 2021). As children mature into young adults, they grow more confident in who they want to be. However, peers and teachers have a lot to do with this process. High schools offer a variety of classes with a wide range of academic rigor. These classes can range from vocational courses to advanced placement courses, intended for students wanting to take college level courses while still in high school. The students who fill up the classes in these courses can be diverse but often follow a distinct pattern. The demographic of AP classrooms in the United States shows that the ratio of female to male students in AP English Literature and Composition is roughly 38% male and 62% female. However, in a STEM class such as AP Chemistry, roughly 68% of the class is taken by male students while 32% is female students (Epic Staff, 2021). These observations raised the question of how, if at all, gender is a factor in the success of female students in English classes and the success of male students in STEM courses.

Literature Review

To understand why women and men are more drawn to professions in English and STEM, it is essential to understand where this preference originates from. A study was done on Finnish ninth graders where they talked about their futures and how they are positively and negatively linked to English and Mathematics (Widlund, 2020). The researchers found that female students were more likely to mention possible careers associated with English and literature when talking about their aspirations and plans for the future. On the other hand, male students mentioned the opposite. Specifically, male students mentioned careers that were more associated with mathematics. Not only were they more interested in careers in these subjects, but when asked which subjects in school they put the most emphasis on, female students often replied with English, and male students replied with math. So not only do female and male students want to pursue careers in each of the subjects, but they also claim to work harder on the specific subjects in school. These researchers were not just looking at test scores. This was solely based on students' feelings towards a particular subject. So, without even analyzing the students' scores in certain sections of standardized tests, researchers were able to prove that girls identify more with English and literature classes than math classes. Not only do female students place more emphasis on these classes, but they also aspire to pursue careers in these subjects as well. It is important to note that students also generally seem to be more involved with particular subjects if their confidence level in those classes is high. “Positive within-domain relations from girls' motivational beliefs were also found, but their reading self-concept was negatively linked to their math-related occupational aspirations. For boys, only math-related motivational beliefs were associated with their aspirations (Widlund, 2020).” In other words, female students seem to be more confident in their aspirations of English-related careers than in mathematics-based careers; for male students, all of their confidence seemed to have lied in mathematics.

While questioning students' interests at the high school level, it is important to consider how environmental influences impact their interests. Students' upbringing will be incredibly

diverse based on socioeconomic status, the schools children attend, and their outside influences. In another study, researchers were determining how a school's socioeconomic status, the teachers' qualifications, and the overall makeup of the school's gender diversity, positively and negatively impact students' reading and math scores. The use of different teaching techniques like frequent quizzes and tests, as well as the use of homework assignments and school projects, affected female and male students differently. Female students consistently scored higher on the reading comprehension tests than their male classmates. Additionally, several other variables highlighting the specific aspects of the student's learning environments were also recorded. Regardless, these variables seem to have had little to no effect on the scores, and female students consistently continued to score higher (Van Hek et al, 2016). This evidence shows that female and male students' success in a subject is loosely based on outside factors, and is in large part affected by societal expectations.

While the outside variables discussed in the previous study were proven to have little effect on the student's success, the following study focuses on mental health. Specifically, it analyzes three different factors: social interactions, performance, and responsibility, that affect females' and males' mental health. This research was conducted amongst 29 focus groups of 16-19 year-old students and dives into their perceptions of the biggest factor of their mental states. It was found that females, more often than males, experienced negative aspects of these three processes mentioned above, putting them at a higher risk for mental health struggles (Landstedt et al, 2009). On the other hand, males experienced generally more positive mental health and showed a lack of responsibility taking. This research also analyzed how feminine and masculine social norms seem to affect female students more than male students. Overall, the data has shown that societal ideals of femininity and masculinity have had an effect on mental health for both females and males. Social factors and processes (particularly responsibility), gendered power relations and constructions of masculinities and femininities should be acknowledged as important for adolescent mental health (Landstedt et al, 2009). The societal expectations of females and males, and more specifically the "power relation" that is mentioned above, show that females are still being encouraged to defer to the power of a male. These idealisms can be confusing for adolescent females as it encourages them to lack the same "go-getter" personality that many of their male classmates possess. Male students possess this personality trait that may encourage them to work harder in classes, leaving the female students behind as they feel the need to let their male classmates take over.

The next study analyzes a younger group of students to determine how early gender roles are accepted by adolescents. In the experiments, first-grade students were asked to, predict academic self-concepts and performance (Wolter et al, 2016). In just first grade, students were already showing signs of gendering, as female and male students already had started to accept gender stereotypes introduced to them, and saw themselves in those stereotypes through their self-concept. It was found that the more feminine a student had described herself, the higher her reading scores were six months later. For male students, the more masculine traits they described themselves, the higher math scores they received (Wolter et al, 2016). At six to seven years old,

children have already made up their minds about femininity and masculinity, and their ideas on the topic are clearly shown through test scores. Through this data, it can be concluded that gender does have an impact on students' test scores due to social influences early on that predetermine children's perceptions of themselves and their roles in society.

Methods:

Based on my own observations at school, there were significantly more male students than female students in many of my advanced science and math classes. This led me to question why male students at my school seem to choose advanced STEM classes over advanced English courses. Potentially, the reason for this discrepancy is the fact that students opt-out of classes they feel they will not be able to thrive in.

I have conducted a project that uses quantitative data from the California Assessment of Student Performance and Progress (CAASPP). This is a state-issued exam that students in California schools take every year from third to eighth grade, and then again in 11th grade. The results from this assessment are public records, and they have been used to analyze the gender gaps between the scores on the English and Math sections of the exam. This study will examine the differences in scores between female and male students in the English and Math sections. The data is based on state-issued exams conducted in authorized testing environments.

This study specifically looks at the year 2017- 2018, to analyze data before the effects of COVID-19 on students. The data was taken before COVID-19 because standardized testing during the pandemic was potentially compromised as was students learning as many classrooms were remote. In the years 2017-18, students were taking standardized tests in traditional testing environments and learning was done in person and inside of a school. This is important to note because the effects of COVID-19 on students' learning varied beyond gender. I have used the achievement level distribution to analyze the number of passing scores and failing scores to assess the differences between the two and determine the disparities between their scores. I have analyzed the data by looking at the differences in the two categories, English and math, of the state tests and separating the scores by gender to specifically see which sections female and male students have the largest differences in.

Analysis

To confirm that female students excel more in English-related classes and male students excel in math-related classes, scores between female and male students on the CAASPP exam were assessed. While analyzing the data between male and female student test scores we found information that supported our hypothesis that female students tend to excel in English-related subjects while male students show a higher level of proficiency in STEM-related subjects.

Table 1: Percentage of students that met or exceeded math and language arts standards in the 2017-2018 CAASPP test

Grade	**Female**	**Male**	**Math Gender**	**Female**	**Male**	**Language Arts**

Level:	Math	Math	Difference (F-M)	Language Arts	Language Arts	Gender Difference (F-M)
3	47.88%	51.44%	-3.56%	52.12%	45.02%	7.1%
4	41.35%	46.59%	-5.24%	52.70%	46.25%	6.45%
5	34.43%	39.42%	-4.99%	54.35%	47.43%	6.92%
11	31.83%	35.66%	-3.83%	61.90%	51.55%	10.35%
Avg.	**38.87%**	**43.28%**	**-4.41%**	**55.27%**	**47.56%**	**7.71%**

This data is from the CAASPP test, which is a statewide exam given in California to students in grades 3-11. This information is public records and can be found on the CAASPP website online.

It is clear from Table 1 that on average 7.71% more female students tended to meet or exceed language arts standards than their male counterparts. When looking at scores from 2017-2018, results showed that on average 55.27% of female students in grades 3-11 met or exceeded the standard in language arts, while an average of 47.56% of male students met or exceeded standards in language arts.

It is also clear from Table 1 that on average 4.41% more male students met or exceeded the math standard than their female counterparts. When looking at scores from 2017-2018, results showed that on average 43.28% of male students in grades 3-11 met or exceeded the standard in math, while an average of 38.87% of female students met or exceeded the math standard. Through the data found, it is clear that there is an association between gender and subject in school as the scores between females and males in the language arts and math categories have significant differences.

Conclusion

Through the math and gender differences highlighted in the table above genders impact on standardized English and math scores become apparent. In the research discussed throughout this paper, the stereotypes of men and women pushed onto children force them to perceive the world with a predisposed opinion. These negative perceptions of society lead children to create standards of themselves that abide by these socially constructed norms. For education, this can lead females to have a lack of confidence in their academic ability in STEM classes, or for male students to pursue only STEM careers. Due to the evidence presented, gender does contribute to academic success in standardized English and math. In the future, we can resist the urge to place children in gender categories and further push societal expectations onto them. These actions will allow children to explore what their own aspirations are and will give them the freedom to pursue careers they are passionate about.

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Being in School Matters: The Status of Chronic Absenteeism in Virginia Public Schools By Winston A. Wang

Abstract

Due to the COVID-19 pandemic, student chronic absenteeism, defined as missing 10 percent of school for any reason, excused or unexcused, has surged in the nation. The current research concentrates on examining the trend of student chronic absenteeism rates in Virginia public schools, with a particular focus on analyzing the data from the 2022-2023 school year. The purpose is to gain a thorough understanding of the status of the chronic absenteeism issue in Virginia, thereby prompting increased attention and the adoption of effective approaches to addressing this issue. This study shows that chronic absenteeism remains a serious issue in Virginia, and it disproportionately affects students of color (including Hispanic, American Indian, and Black students), students with disabilities, English learners, low-income students, homeless students, kindergarteners, and grade 12 students, as well as schools in the Piedmont region. Higher rates of chronic absenteeism were found to be associated with lower Virginia state assessment pass rates for all subjects – English reading, mathematics, science, history/social science, and English writing. Future studies are proposed to extend the current research.

Introduction

As a high school student, every quarter I go through the familiar ritual of receiving my school report card, eagerly scanning the grades and comments for each subject. However, nestled among the grades is a reminder of my attendance record: the number of days I was absent. Initially, it seemed like just another statistic. Yet, a simple question lingered in my mind: Why does this matter? This curiosity sparked a journey of exploration into the topic of chronic absenteeism among students.

Chronic absence is defined as missing 10 percent of school—the equivalent of two days every month or 18 days over a 180-day school year for any reason, excused or unexcused. The 2015 Every Student Succeeds Act (ESSA) required that all states collect chronic absence data in their school report cards. Since then, chronic absenteeism has evolved from an unfamiliar notion to a critical education metric for school accountability (Chang, Bauer & Byrnes, 2018). Due to the COVID-19 pandemic, chronic absenteeism surged from 15 percent in 2018 to 28 percent in 2022 (Malkus, 2024). On September 13, 2023, the White House published a blog entry presenting data indicating that chronic absenteeism significantly contributes to the recent steep decline in students' performance on the National Assessment of Educational Progress, while advocating for solutions to address this issue.

The Virginia Department of Education (VDOE) diligently assesses chronic absenteeism as a growing concern within school divisions and among educators, providing valuable insights into the school learning climate. However, the available information on its website (https://schoolquality.virginia.gov/virginia-state-quality-profile#desktopTabs-6) is limited in the following areas:

1. The data covers only three school years: 2020-2021, 2021-2022, and 2022-2023.

2. It exclusively presents state-level data and omits division-specific details.
3. It doesn't relate chronic absenteeism to student academic achievement.

VDOE provides data on chronic absenteeism at state, division, and school levels from 2015-2016 to 2022-2023 school years. A deeper dive into the data on chronic absenteeism can provide a comprehensive picture of the chronic absenteeism issue faced by Virginia public schools before proactive measures are enacted to tackle the underlying causes.

The study concentrates on examining the trend of student chronic absenteeism rates in Virginia, with a particular focus on analyzing the data from the 2022-2023 school year. The aim is to identify high-risk student subgroups and divisions, thereby prompting increased attention and the adoption of more effective approaches to addressing this issue.

The data, obtained from the website of VDOE, were analyzed and reported in two aspects:

(1) Trends in chronic absenteeism between school year 2015-2016 and 2022-2023, which included overall trend, trend by grade level and trend by racial/ethnic groups.
(2) An in-depth analysis of the 2022-2023 school year data, delving into student chronic absenteeism rates by race/ethnicity, special student groups, grade levels, and school divisions, which consist of counties and county-equivalent cities. Additionally, the chronic absenteeism rate was associated with the Virginia state assessment pass rate.

Methods

The findings presented in this document were based on information and data obtained through searches of published articles on the topic of chronic absenteeism and exploration of the websites of the Federal and the Virginia Department of Education. The datasets were acquired from Virginia Department of Education (VDOE). In total, eleven datasets were downloaded and processed for the research.

Step 1: Defining research questions.

Digital articles, news, posts, and reports on chronic absenteeism and its impact on student achievement were obtained from The Washington Post, Attendance Works (a non-profit research organization), and Johns Hopkins University Hub via google search. The gathered information was used to define the study goal and identify the necessary data to answer the research questions.

Step 2: Searching for data.

Data search started from the website of the U.S. Department of Education. Two websites were carefully explored: ED Data Express, a website designed to provided state- and district-level education data collected by the U.S. Department of Education (ED), and ED*Facts*, an initiative of ED to collect from state education agencies prekindergarten through grade 12 education data. The datasets on chronic absenteeism of Virginia were found, but they only contained counts of students chronically absent. Without the number of total enrollments, the percent of chronic absence could not be calculated. To obtain the enrollment data, a search on the

website of VDOE was conducted and eleven datasets were found to be relevant to the research. Those datasets were downloaded to be analyzed.

Step 3: Data cleaning and compiling.

Using sort and filter functions in Excel, data cleaning and compiling were conducted to generate the final datasets for analyses, including:

- State data of all students: 2015-2022
- State data by student groups: 2015-2022
- State data by grade level: 2015-2022
- 2022-2023 state data of all students and by student groups
- 2022-2023 local education agency (LEA) or school division data
- 2022-2023 SOL assessment pass rate data by state, school divisions and subjects

Step 4: Analyses

Final datasets were analyzed with Excel and Tableau, a visual analytics platform.

Results

1. Trend in chronic absenteeism between school year 2015-2016 and 2022-2023

This section shows the overall trend in chronic absenteeism in Virginia schools and the trend line by grade level and by race/ethnicity between the school years 2015-2016 and 2022-2023. Figure 1 presents the average chronic absenteeism rate in Virginia schools from 2015 to 2022.

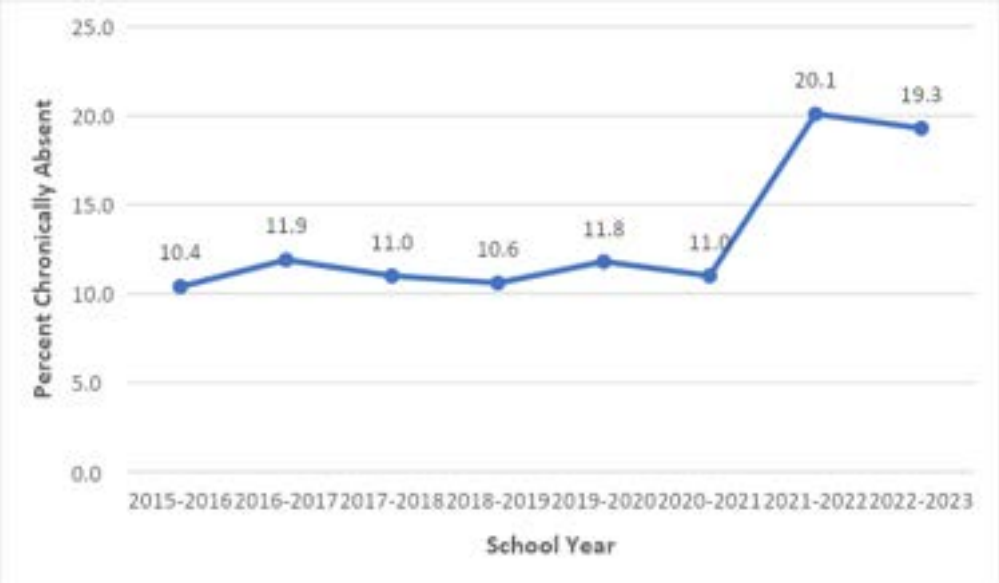


Fig 1. Trend in chronic absenteeism in Virginia

Between school years 2015-2016 and 2020-2021, the chronic absenteeism rate was quite stable, ranging between 10.4 and 11.9 percent. In school year 2020-2021, instructions were delivered in a hybrid mode in Virginia public schools: some happened in-person and some took place via remote learning. In school year 2021-2022, when Virginia schools all opened for full-time, in-person learning, the chronic absenteeism rate nearly doubled (increased by 10

percentage points). Last school year (2022-2023), 19.3 percent of students across Virginia were chronically absent, which was lower than 2021-2022. However, this rate is still high, suggesting that schools in Virginia continue to struggle with chronic absenteeism following the COVID pandemic.

Figure 2 below displays the trend between 2015 and 2022 by grade level. A similar pattern of chronic absent rates can be seen for all grades except kindergarten and grade 12. Grade 12 students show the highest chronic absenteeism rates in all school years, except 2020-2021. The rate of grade 12 students dropped from 19.2% in the school year 2019-2020 to 11.9% in the school year 2020-2021. However, the rate drastically increased to 27.7% after the pandemic and then slightly dropped to 26% in the last school year. Different from other grade levels, the rates for kindergarten kids maintained an increasing trend from school year 2020-2021 when the pandemic started to the past school year, 2022-2023. Its rate (25.2%) was about the same as grade 12 students in the last school year of 2022-2023. This increasing pattern is concerning.

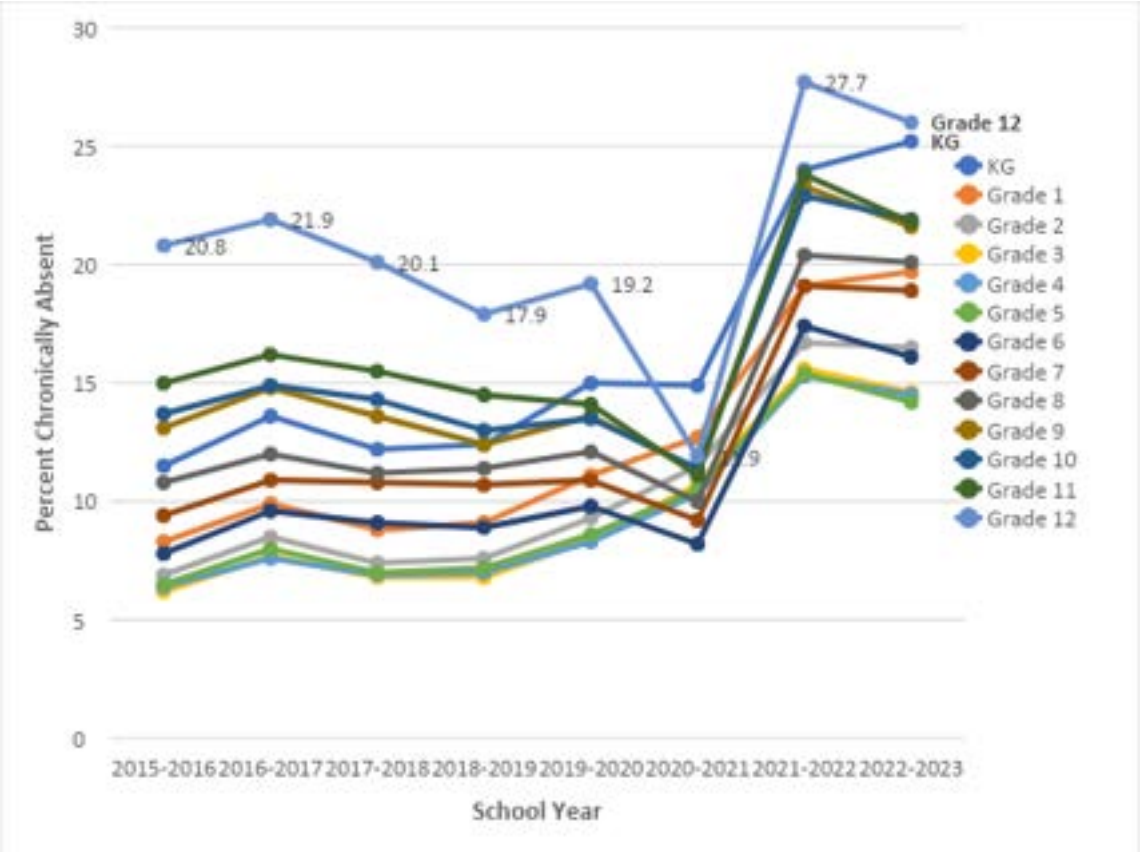


Fig 2. Trend in chronic absenteeism by grade level in Virginia

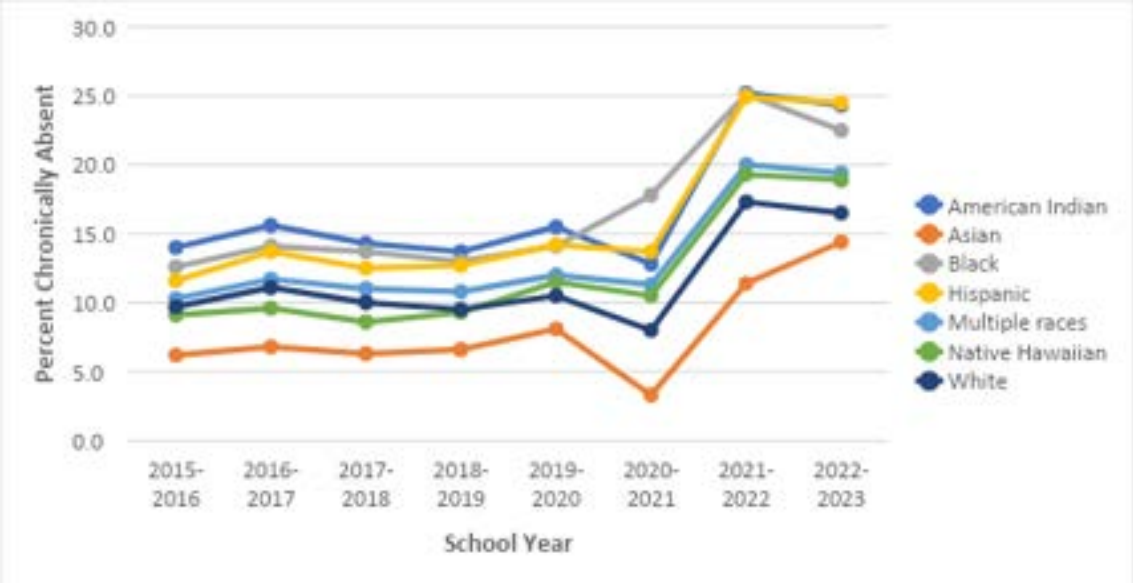


Fig 3. Trend in chronic absenteeism by race/ethnicity in Virginia

Figure 3 illustrates the trends by race/ethnicity. The trend pattern of chronic absenteeism rates looks similar for all racial/ethnic groups – the trend line was quite flat between 2015 and 2019, dropped in 2020 (except for Black students), and then reached a historic high in 2021. Last school year (i.e., 2022-2023) showed a small decline in chronic absenteeism rates for all racial/ethnic groups except Asians. For the school years between 2015 and 2022, students who identified as American Indian, Black, and Hispanic students were chronically absent at consistently higher rates than other racial/ethnic groups.

2. A drill down of school year 2022-2023 data

This section presents a closer look at the chronic absenteeism data of the last school year (2022-2023). The average percent of chronic absence was 19.3 in the 2022-2023 school year (figure 4). Asian and White students had the lowest rates of chronic absenteeism, whereas Hispanic and American Indian students had the highest rates. For both Hispanic and American Indian students, chronic absenteeism rates (24.5% and 24.3%, respectively) were ten percentage points higher relative to Asian students (14.4%) and eight percentage points higher relative to White students (16.5%).

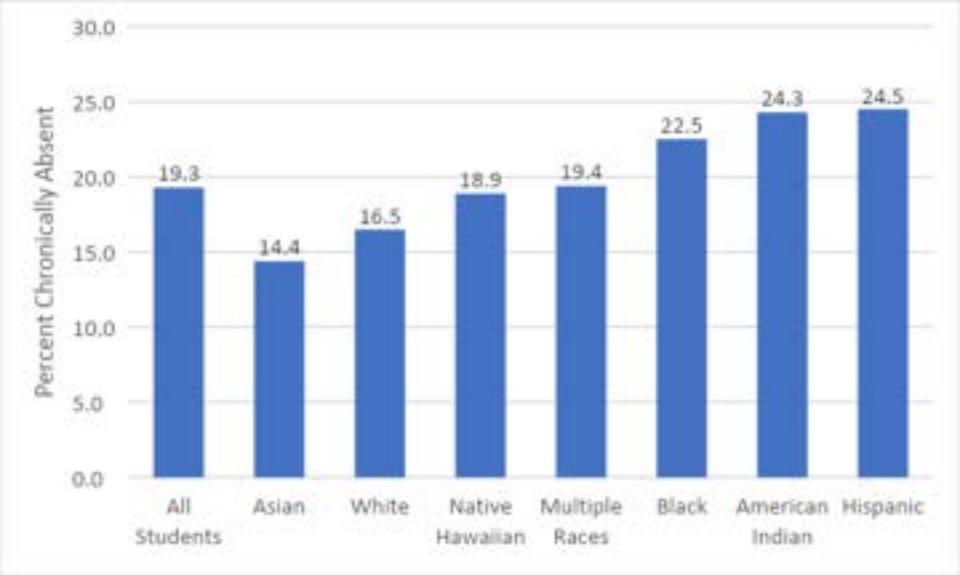


Fig 4. Chronic absenteeism by race/ethnicity in Virginia: School year 2022-2023

As Figure 5 shows, special service groups, including students with disabilities, economically disadvantaged students, and English learners, all had higher chronic absenteeism rates than the average rate in Virginia in school year 2022-2023. Homeless students had a rate close to 50%, which was the highest among all student groups.

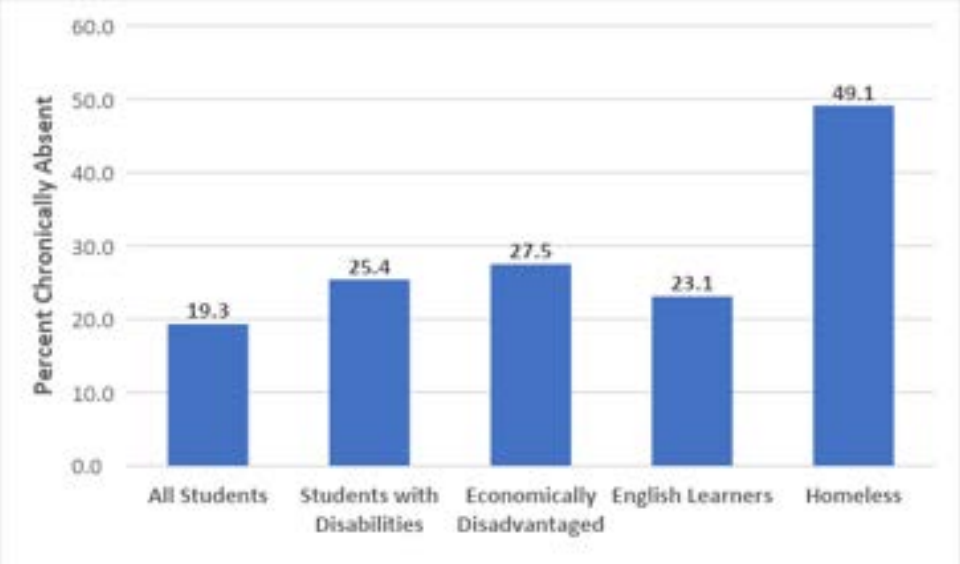


Fig 5. Chronic absenteeism by student group in Virginia: School year 2022-2023

Figure 6 presents the absenteeism rates by grade level. Chronic absenteeism occurred at every grade level but was more prevalent in some grades than others. In school year 2022-2023, chronic absenteeism was the lowest in grades 3, 4, and 5 (lower than 15%) and the highest in kindergarten and grade 12 (both higher than 25%).

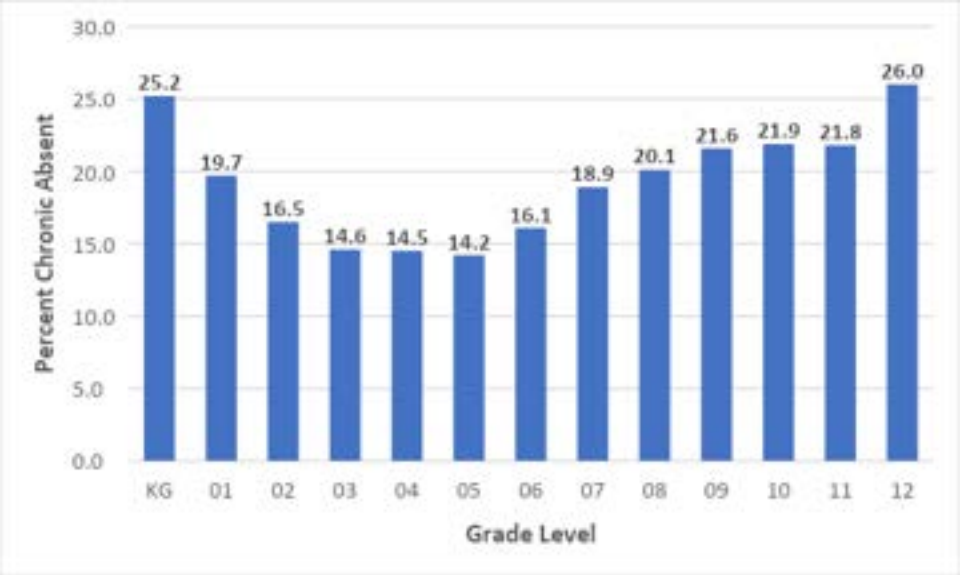
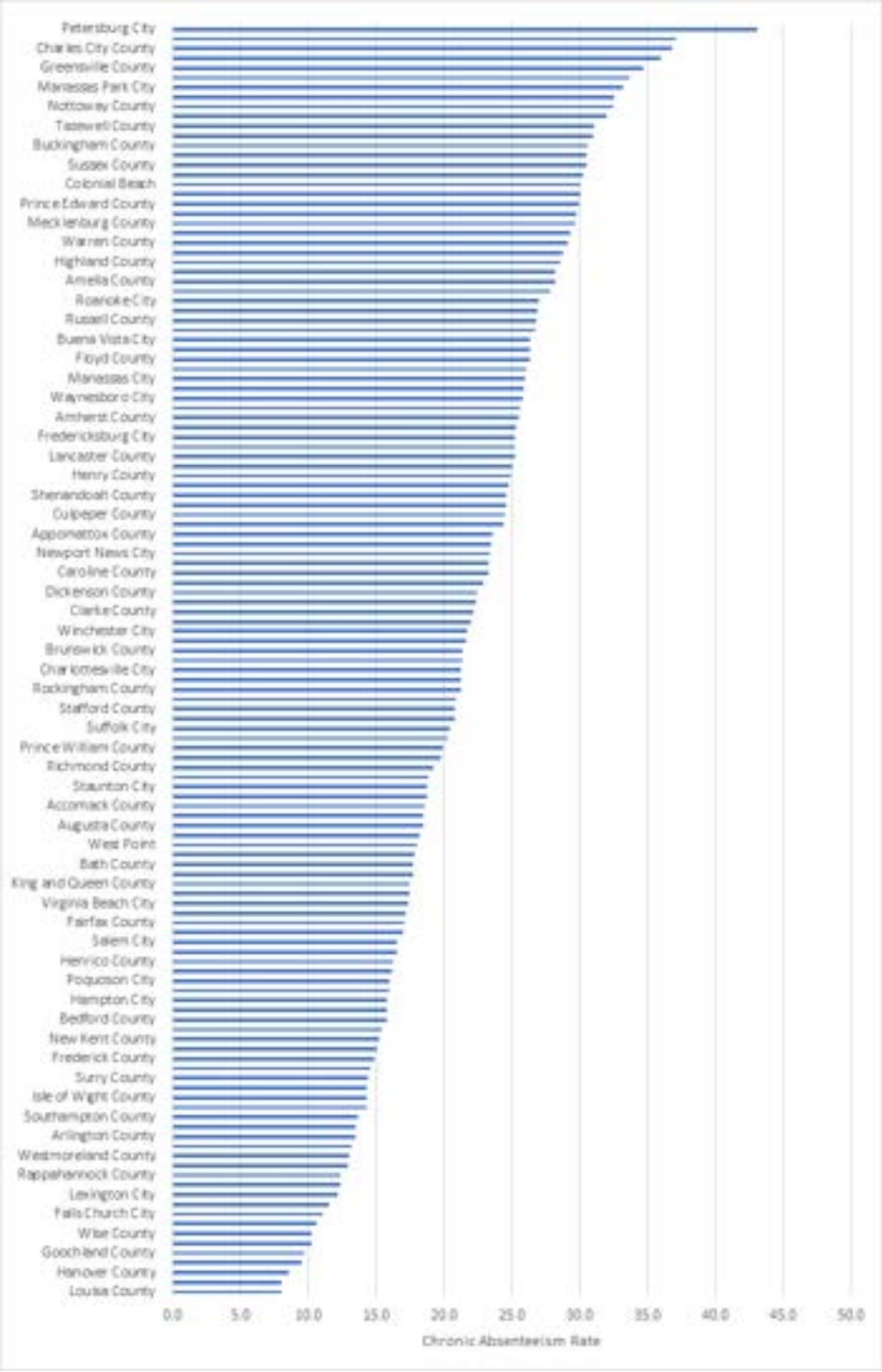


Fig 6. Chronic absenteeism by grade level in Virginia: School year 2022-2023

Figure 7 displays the chronic absenteeism rates by school division (including county and county-equivalent city) from the highest to the lowest. In Virginia, there are 95 counties and 38 independent cities that are considered county-equivalents for census purposes. The data obtained from VDOE only contain 131 divisions. One county and one city are missing from the dataset. Among 131 counties and cities, Petersburg City had the highest chronic absenteeism rate (43.1%) and Louisa County and Radford City had the lowest rate (8.0%) in school year 2022-2023.



Note: This chart does not have enough space to render all county and city labels.

Fig 7. Chronic absenteeism rate by county and county-equivalent city in Virginia: School year 2022-2023

The school division level chronic absenteeism rates are displayed on the state map in Figure 8 using Tableau. The Piedmont region appears to have a high concentration of school divisions with relatively higher chronic absenteeism rates, indicated by darker colors.

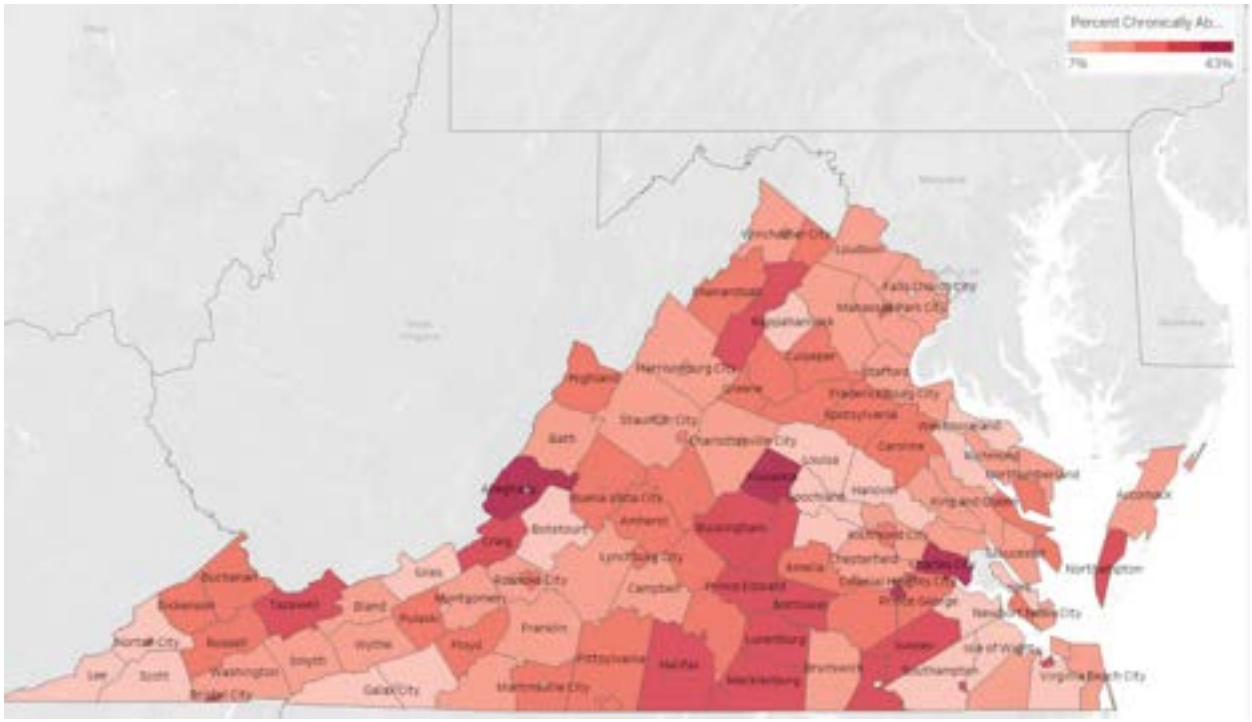


Fig 8. Heat map of chronic absenteeism rates by school division: School year 2022-23

Figure 9 provides a frequency distribution of school divisions (i.e., counties and county-equivalent cities) by the chronic absenteeism rate. Only 8 divisions had a rate lower than 11%, which was the average chronic absenteeism rate in school year 2020-2021. There are 46 (i.e., 35%) counties/cities which have a rate higher than 25%.

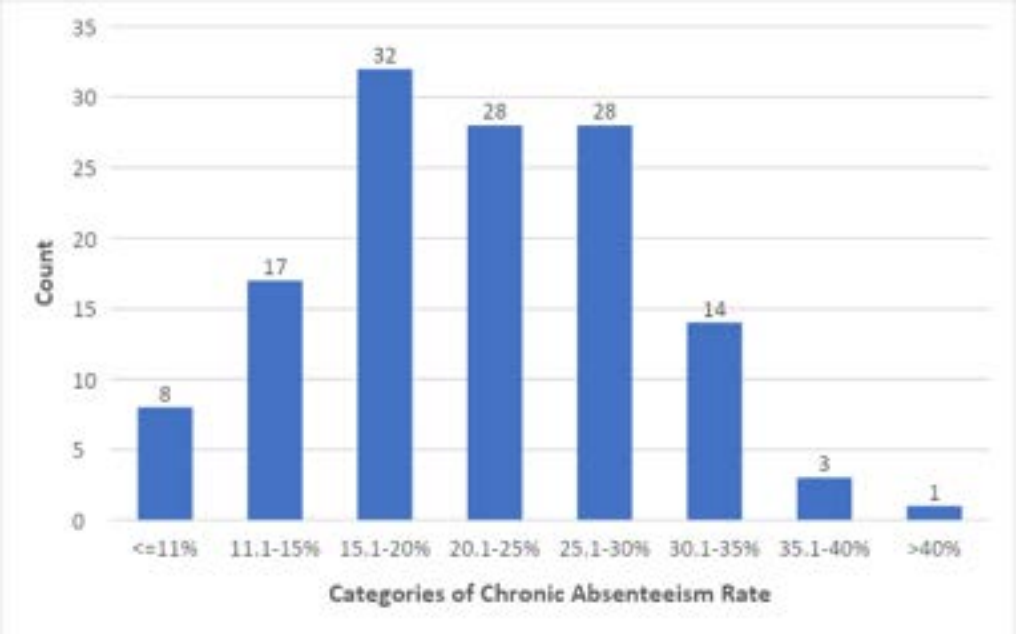


Fig 9. Counts of counties and county-equivalent cities by the chronic absenteeism rate: School year 2022-2023

Does it matter if students show up in the school or not? VDOE established the Standards of Learning (SOL) for Virginia Public Schools, which set minimum expectations for what students should know and be able to do at the end of each grade or course in different subjects. Table 1 presents the SOL test results of the last school year (2022-2023) of the whole state and 2 selected counties. The statewide average pass rates for tests in reading, mathematics, science, history/social science, and writing ranged from 65% to 73%. Louisa County, which had the lowest chronic absenteeism rate (8.0%), had higher SOL pass rates for all 5 subjects than Petersburg City, which had the highest chronic absenteeism rate (43.1%) in 2022-2023. The pass rates of Louisa County for all 5 subjects were higher than the state average pass rates too.

Table 1. State SOL test pass rate of the whole state and selected counties: School year 2022-2023.

Subject	Statewide	Petersburg City	Louisa County
Reading	73%	45%	76%
Mathematics	69%	37%	79%
Science	67%	33%	78%
History/Social Science	65%	37%	75%
Writing	65%	29%	69%

Note: The passing score for the Virginia SOL tests is 400 based on a reporting scale that ranges from 0 to 600. A scaled score of 0 to 399 means a student did not pass a test. The pass rate indicates the proportion of students with an SOL score of 400 or higher.

The correlation between the SOL test pass rate and the chronic absenteeism of all school divisions in school year 2022-2023 is negative for all subjects (see Table 2). The correlation is

stronger for reading, mathematics, and science (-.57, -.56 and -.54) than for writing and history/social science (-.46 and -.43). The magnitude between .50 and .70 is usually considered as a moderately strong relationship.

Table 2. The correlation between Virginia SOL test pass rate of school divisions and the chronic absenteeism of school divisions: School year 2022-2023

SOL Test Subject	Chronic Absenteeism Rate
Reading	-0.57
Math	-0.56
Science	-0.54
Writing	-0.46
History/Social Science	-0.43

Summary and discussions

Chronic absenteeism has been tracked by the federal government and states as a relatively new measure of school climate or quality. This study drilled down into Virginia state- and school division-level data on the student chronic absenteeism rate to examine the status of the issue in Virginia public schools. Major findings include the following:

(1) Trend of chronic absenteeism rates

The chronic absenteeism rate in Virginia public schools was stable until school year 2020-2021 and nearly doubled in school year 2021-2022 when public schools resumed full-time, in-person instructions. A significant conjecture posits that the widespread adoption of exclusively remote instruction in public schools during the 2020 to 2021 closures potentially exacerbated the issue of chronic absenteeism. This assertion is grounded in the observable impact of remote learning on students' behavioral patterns and academic engagement (Dee, 2024). Dee's investigation provides empirical support for this conjecture, revealing a positive correlation between the duration of remote-only instruction during the 2020-2021 school year and the increase in chronic absenteeism.

The trend pattern of the chronic absenteeism rate in the last eight school years was largely similar for all grade levels. Grade 12 students consistently showed the highest chronic absenteeism rates than other grade levels except in school year 2020-2021. The underlying reason for the decline in chronic absenteeism among twelfth-grade students during the 2020-2021 school year is unclear.

All racial/ethnic groups demonstrated a similar trend pattern of the chronic absenteeism rate in the last eight school years. Across all eight school years, Asian students were least likely to have experienced chronic absenteeism, while American Indian, Black, and Hispanic students were most likely to do so. The finding of disparities aligns with the nationwide data on chronic absenteeism (U.S. Department of Education, 2016).

(2) Status of chronic absenteeism in the 2022-2023 school year

The average percent of chronic absence was 19.3 in the 2022-2023 school year. This translates into nearly 1 out of 5 students being chronically absent from Virginia public schools. It is obvious that chronic absenteeism continues to remain a serious issue a year after the Virginia schools resumed full-time, in-person instructions.

Chronic absenteeism disproportionately affects students from certain racial and ethnic minority backgrounds (including Hispanic, American Indian, and Black students) as well as students with disabilities, students in poverty, and English language learners. Homeless students had a rate close to 50%, which is the highest among all student groups. Although the patterns of disparities are evident, our understanding of the pathways leading to these inequalities remains limited. The interconnected nature of the factors contributing to these disparities complicates the task of pinpointing and addressing the root causes of absenteeism gaps (Gee, 2018).

By grade levels, chronic absenteeism was the lowest in grades 3, 4, and 5 and the highest in kindergarten and grade 12. The high rate of absenteeism in kindergarten (more than 25%) is especially concerning because studies have found that kindergarten chronic absenteeism was linked to lower test scores in 3rd grade (Superville, 2023) and lower working memory and cognitive flexibility outcomes (Gottfried & Ansari, 2021).

Absenteeism was not evenly distributed across Virginia: The Piedmont region has a high concentration of counties and county-equivalent cities with higher chronic absenteeism rates. Disturbingly, among 131 school divisions (including 94 counties and 37 county-equivalent cities), 46 divisions had a chronic absenteeism rate higher than 25%, meaning 1 out of 4 students in more than one third of the Virginia school divisions were chronically absent in the 2022-2023 school year.

Higher rates of chronic absenteeism were associated with lower Virginia SOL test pass rates for all subjects (i.e., reading, mathematics, science, history/social science, and writing). Gottfried's (2019) study shows that chronic absenteeism not only harms individuals who miss excessive school days, but also has the potential to negatively impact the academic achievement of their classmates who are not chronically absent. Reducing as few as 10 absences per year could greatly increase the likelihood of students graduating high school and enrolling in college (Liu, Lee & Gershenson, 2021).

Numerous strategies exist to tackle the challenge of student absenteeism. The Institute of Education Sciences (IES) within the U.S. Department of Education released a handout outlining strategies derived from a literature review conducted by researchers at REL Southwest. However, due to the multifaceted nature of student absenteeism, there is no one-size-fits-all solution. A future study is needed to find out whether VDOE collects data on the reasons behind absenteeism. Analyzing and summarizing these reasons will offer a more comprehensive understanding of the extent of chronic absenteeism among Virginia public schools.

Future analytical inquiries can also delve into assessing the impact of chronic absenteeism on student academic performance at both division and school levels. Furthermore, analyses of the data can explore the relationship between chronic absenteeism rates and school characteristics (e.g., the proportion of economically disadvantaged students and the financial

status of schools), aiding in the identification of schools most susceptible to high rates of chronic absenteeism.

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Systems for Improving the Accessibility of Drinking Water Using Hydropower Plants By Marina-Irina Suvac

Abstract

Water is considered the source of life on Earth, but not all people have equal access to potable water. Clean water and sanitation constitute the sixth global goal of current society, with measures being taken daily to ensure their accessibility and sustainable management (Goal 6: Clean water and sanitation - the global goals, n.d.). The purpose of this research paper is to ensure internationally the theoretical structures necessary for the creation of potable water installations accessible to all people using hydroelectric power plants. Using online simulators and physical experiments, this research helped develop a theoretical system for the use and distribution of water used by hydroelectric plants in domestic potable water installations internationally. This research was guided by physical and chemical experiments necessary for developing advanced methods for decantation, softening, filtration, desalination, and purification of water with minimal financial consumption. Initial studies and scientific research were conducted to ensure an innovative method for reducing costs associated with the production of potable water and hydro energy and increasing their accessibility internationally. The initial study's findings show that 3% of a person's gross monthly salary is spent on securing water and that only 66.975% of the water a person drinks is potable. Findings also indicate that by using the developed theoretical water use and distribution system, the costs of decantation and transportation of water can be reduced to zero, while those of softening, filtration, and desalination can decrease significantly. Therefore, a change regarding the accessibility of potable water globally is of paramount importance and this system reduces the costs of hydropower production and makes drinking water more accessible, which can be directly distributed to domestic drinking water installations.

Identified Problem to be Solved

Factors such as financial situation and geographical location of residence are the strongest sources of inequality regarding the availability of potable water. A personal study conducted in 2024 in Romania with 148 participants shows that, on average, many people, 64.2% of whom live in a plains geographical area like Moldova, consider the current price of potable water to be very high (4.219 on a scale from 1 to 5, where 5 represents a very high cost). On average, they choose to drink 0.642 liters of non-potable water every day due to their financial situation.

International studies show that currently millions of people do not have access to potable water, an example being the report by the United Nations Children's Fund (UNICEF) and the World Health Organization (WHO) in 2019. International

organizations have declared that "1 in 3 people globally do not have access to potable water" (World Health Organization: WHO, 2019).

Therefore, a change regarding the accessibility of potable water globally is of paramount importance.

Project Stages

Stage	Execution of the Stage	Outcomes of the Stage	Timing of the Stage
Stage 1	Selection of the research field, formulation of the researched topic, and delimitation of the study area.	Following this stage, I chose to create a paper aimed at making potable water accessible using hydroelectric plants based on a personal study that will highlight the problems identified nationally in March-April 2024.	January 2024
Stage 2	Creating the personal study questionnaire considering current international societal issues.	Following this stage, I created an anonymized online questionnaire with an initial sample of 148 people nationally, which will be continued internationally over the following months.	March 2024
Stage 3	Analyzing the responses to the personal study questionnaire with an initial sample of 148 people.	Following this stage, I created the necessary statistics and graphs to complete the national study, highlighting the identified problem.	April 2024
Stage 4	Analyzing the relevant international specialized literature for the chosen research field.	Following this stage, I familiarized myself with similar studies and research projects already conducted, identifying the strengths and weaknesses of the personal study.	February-April 2024
Stage 5	Choosing the research procedure and instruments, and establishing the expected results considering the personal study and international specialized literature.	Following this stage, I decided to conduct physical and chemical experiments and online simulations to demonstrate the formulated hypotheses.	January-March 2024
Stage 6	Conducting physical and chemical experiments for decantation, softening, filtration, desalination, and purification of water and recording the results.	Following this stage, basic experimental data of the research project at a scientific level resulted.	January-April 2024
Stage 7	Conducting online simulations and physical experiments to develop a theoretical system for the use and distribution of water used by hydroelectric plants in domestic potable water installations and recording the results.	Following this stage, experimental data and essential details of the experiments at a scientific level resulted.	February-April 2024
Stage 8	Analyzing the initially established hypotheses and the experimental data and essential details of the experiments, establishing the conclusions of the research project based on the initial study.	Following this stage, conclusions supporting the innovative method for reducing costs associated with the production of potable water and hydro energy and increasing their accessibility internationally resulted.	May 2024
Stage 9	Creating a summary of the paper based on the initial personal study delimited nationally.	Following this stage, I highlighted the research project and its findings.	May 2024

Methods Used

1. Initial personal study with an initial sample of 148 people conducted in March-April 2024

- Research procedure: The personal study involves creating an anonymized online questionnaire with an initial sample of 148 people nationally, which will be continued internationally over the following months, and analyzing the responses to highlight the obtained statistics and graphs.
- Research tools: Google Forms application
- Expected results: Observing the issue of water accessibility considering the geographical area of residence and the financial situation of individuals; Observing the high costs of potable water compared to those of water from domestic installations.

2. Scientific research conducted through physical and chemical experiments and online simulations from January to April 2024

Experiments/ Online Simulation	**Research Procedure**	**Research Tools**	**Expected Results**
Water Decantation (Annex 1)	The experiment uses gravitational force to extract solid sediments suspended in the liquid.	● Berzelius Beaker	● Reduction of water turbidity (content of organic substances in processed water); ● Preparation of water for the softening experiment.
Water Softening (Annex 2)	In the experiment, using a water softener, the calcium in the water is replaced with sodium (in the form of sodium chloride, NaCl).	● Water Softener	● Reduction of water hardness (partial or complete removal of calcium and magnesium ions from processed water); ● Preparation of water for the filtration experiment.

Water Filtration (Annex 3)	The experiment uses a laboratory-made filtration installation to eliminate very fine impurities from water by forcing the liquid through a porous material.	● Berzelius Beaker ● Filtration Funnel ● Filter Paper ● Support Rod ● Clamp	● Reduction of the amount of very fine impurities in processed water; ● Preparation of water for the desalination experiment.
Water Desalination (Annex 4)	The experiment is based on the reverse osmosis technique (certain pumps push water through membranes that only allow water molecules to pass, not salt ones).	● Partially Permeable Membrane ● Laboratory Glasswar e (the container where reverse osmosis occurs)	● Reduction of water salinity (salt content in processed water); ● Preparation of water for the purification experiment.
Water Purification	The experiment involves conducting complementary chemical, physical, and biological processes.	● UV Sterilizer ● Water Treatment Installations	● Separation of potable water from impurities.
Online Simulation of a Theoretical System	The online simulation involves creating a theoretical system for using water used by hydroelectric plants	● Online Simulator Insight Maker	● Creation of an animated graphic scheme of the theoretical system for using

for Using Water Used by Hydroelectric Plants (Annex 5)	(stored on the lower water level side of the dam), considering the known structure and operation of hydroelectric plants.	● Graphic Design Tool Canva	water used by hydroelectric plants; ● Preparation of the theoretical model for practical implementation.
Online Simulation of a Theoretical System for Distributing Water Used by Hydroelectric Plants in Domestic Potable Water Installations (Annex 6)	The online simulation involves creating a theoretical system for distributing water used by hydroelectric plants in domestic potable water installations, considering the known structure and operation of hydroelectric plants and the existence of the theoretical system for using this water.	● Online Simulator Insight Maker ● Graphic Design Tool Canva	● Creation of an animated graphic scheme of the theoretical system for distributing water used by hydroelectric plants; ● Preparation of the theoretical model for practical implementation.
Influence of Potable Water Production on Resulting Hydroenergy	In the experiment, using previously established experimental data, the influence of potable water production on the costs associated with hydroenergy production and its accessibility is analyzed.	● Graphs ● Statistics ● Experimental Data	● Reduction of costs associated with both potable water production and hydroenergy production; ● Increase in the accessibility of potable water and hydro energy.

Experimental Data and Essential Experiment Details

1. Initial personal study with an initial sample of 148 people conducted in March-April 2024

- Experimental Data (Annexes 7, 8, and 9):

i. 98% of respondents believe that drinking water is vital to modern society;
ii. On average, respondents earn a gross monthly salary of approximately 5374.725 lei;
iii. On average, respondents pay approximately 67.905 lei for approximately 5636 liters of water consumed per month using household water installations;
iv. On average, respondents drink approximately 1.944 liters of water per day, which amounts to approximately 58.32 liters per month;
v. On average, respondents drink approximately 0.642 liters of non-potable water per day, which amounts to approximately 19.26 liters per month;
vi. On average, respondents pay approximately 93.565 lei for approximately 32.907 liters of drinking water purchased per month;
vii. On average, respondents consider drinking water important for people's health at 98.38% (4.919 out of 5);
viii. On average, respondents would be influenced by a decrease in the price of drinking water in their decision to stop consuming non-potable water at 78.38% (3.919 out of 5);
ix. On average, respondents consider the current price of drinking water to be very high (4.219 on a scale of 1 to 5, where 5 represents a very high cost);
x. On average, respondents are considering purchasing a water purification mechanism at 75.06% (3.753 out of 5).

- Essential Study Details:

i. The study considered diversity and social inclusion, with the questionnaire completed: by 45.9% males and 54.1% females; by people from various age groups, from 15-20 years to over 80 years; by people with various levels of education;
ii. The study considered geographic and financial diversity, with the questionnaire completed: by 69.6% urban and 30.4% rural residents; by 64.2% from Moldova, 22.3% from Transylvania, and 13.5% from Oltenia, Dobrogea, Banat, Muntenia, and Basarabia; by 61.5% employed and 38.5% unemployed; by 44.6% from the private sector and 55.4% from the public sector; by 34.5% from the primary sector, 14.2% from the secondary sector, 31.8% from the tertiary sector, and 19.6% from the quaternary sector.

- Data Analysis and Explanation of Processes and Phenomena Studied:

i. According to processed experimental data, in a month, a person earns a gross salary of 5374.725 lei and pays 67.905 lei for 5636 liters of water consumed using household installations and 93.565 lei for 32.907 liters of drinking water purchased (which means 3% of the gross monthly salary is spent on water);
ii. Due to the high price of drinking water, a person drinks 19.26 liters of non-potable water out of the total 58.32 liters of water drunk in a month (which means only 66.975% of the water drunk is potable);
iii. The cost difference between the price of drinking water (2.843 lei/liter) and water from household installations (0.012 lei/liter) is significant, facilitating the choice of non-potable water over potable water;

iv. Most people consider drinking water important for health, but consider the current price very high and would be influenced by a price reduction in their decision to stop consuming non-potable water.

2. Scientific Research Conducted Through Physical and Chemical Experiments and Online Simulations on a 500 ml Sample of Surface Water from a Predominantly Plain Area (Danube River, Galați County, Romania) in January-April 2024

Experiments/Online Simulation	**Experimental Data**	**Essential Experiment Details**	**Data Analysis and Explanation of Processes and Phenomena Studied** (+ cost analysis according to the studies)
Decantation of Water	● Initial amount of surface water subjected to decantation: 500 ml ● Final amount of water after decantation: 412 ml	● 88 ml of impurities separate through decantation	Water losses during decantation vary from 5% in developed countries to 60-70% in underdeveloped ones. (Alin, 2018)
Water Softening	● Initial amount of water subjected to softening: 412 ml ● Final amount of water after softening: 384 ml	● 28 ml of water is consumed during the softening process ● Processed water has a hardness of 25 German degrees ● The softening station contains 25 liters of resin	For a water consumption of 250 liters/day/person with a hardness of 25 German degrees, a 25-liter resin softening station consumes 365 kg of salt/year, costing approximately 981.85 lei/year. (H2o Molecula, 2013)
Water Filtration	● Initial amount of water	● 11 ml of very fine impurities	Decanted water still contains very fine impurities, making

	subjected to filtration: 384 ml ● Final amount of water after filtration: 373 ml	separate through filtration	filtration necessary for higher-quality water purification.
Water Desalination	● Initial amount of water subjected to desalination: 373 ml ● Final amount of water after desalination: 86 ml	● 287 ml of water is consumed during the desalination process ● The reverse osmosis process has a yield of 23.06%	The reverse osmosis process yield ranges from 10-25%. (H2o Molecula, 2013)
Water Purification	● Initial amount of water subjected to purification: 86 ml ● Final approximate amount of water after purification: 86 ml	● 0.000022 ml of chlorine is added during the purification process by treating the water with chlorine, i.e., 0.4 mg chlorine/liter of water	The World Health Organization states that the amount of chlorine in drinking water can range from 0.2 mg/l to 1 mg/l, with chlorine use being the safest and most frequent method for eliminating viruses and bacteria. (International Agency for Research on Cancer, 1991)
Online Simulation of a Theoretical Syste	● Potential energy obtained by using the hydroelectric plant: 73279.5 J	● Difference in water level on both sides of the dam: 15 m ● Hydroelectric plant efficiency is 90%	By operating the hydroelectric plant, 65951.55 J of electrical energy can be obtained, and 86 ml of potable water can be obtained through the theoretical system (500

m for Using Water Used by Hydroelectric Power Plants	● Electrical energy obtained by using the hydroelectric plant: 65951.55 J ● Amount of water needed to obtain the mentioned electrical energy: 500 ml ● Amount of potable water obtained: 86 ml	● Gravitational acceleration is considered to be 9.8 m/s²	ml of surface water results in 86 ml of potable water through purification methods). Modern hydroelectric plants have an efficiency of up to 90%. (Killingtveit, 2020)
Online Simulation of a Theoretical System for Distributing Water Used by Hydroelectric Power Plants in Dome	● Initial amount of potable water distributed: 86 ml ● Final approximate amount of potable water after distribution: 86 ml	—	Potable water losses during the distribution of water used by hydroelectric plants in domestic potable water installations are considered negligible.

stic Potable Water Installations			
Influence of Potable Water Production on Resulting Hydropower	—	● The theoretical system reduces decantation costs to 0.	Costs associated with both potable water production and hydropower are significantly reduced, and the accessibility of potable water and hydropower increases.

Conclusions

Following the initial study and scientific research, some of the initially established hypotheses were proven, and experimental data were obtained that support the provision of an innovative method for reducing costs associated with the production of drinking water and hydropower and for increasing their accessibility at the international level. Thus, a change regarding the accessibility of drinking water worldwide continues to be of paramount importance.

The initial personal study showed that 3% of a person's gross monthly salary is spent on securing water, that only 66.975% of the water a person drinks is potable, and that the cost difference between the price of drinking water (2.843 lei/liter) and that of water from household installations (0.012 lei/liter) is considerable. These facts facilitate the choice of non-potable water over potable water. Additionally, most people consider that potable water is important for human health but believe that the current price of drinking water is very high and would be influenced by a price decrease in their decision to stop consuming non-potable water.

Following scientific research, a theoretical system for the use and distribution of water used by hydropower plants in domestic drinking water installations and some advanced methods of decantation, softening, filtering, desalination, and water purification with minimal financial consumption have been developed.

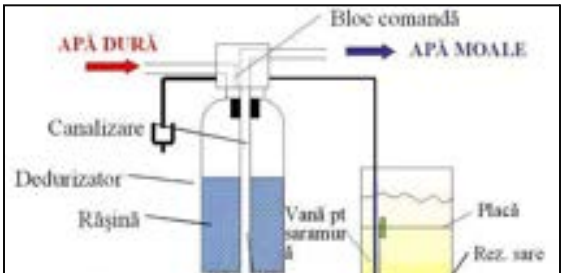
The physical and chemical experiments conducted showed that from an initial amount of 500 ml of surface water subjected to the five processes, the approximate final

amount of water obtained was 86 ml. Online simulations showed that by operating a hydropower plant with a height difference of 15 m and an efficiency of 90%, 65,951.55 J of electrical energy can be obtained, and 86 ml of drinking water can be distributed using the developed theoretical water use and distribution system (using only the 500 ml of surface water). Consequently, the costs associated with the decantation and transport of water can be reduced to zero, while the estimated costs of softening, filtering, and desalination can decrease significantly. Additionally, reusing hydropower plant water benefits the natural environment and reduces the costs associated with hydropower production. Thus, by reducing costs, drinking water is made more accessible both financially and geographically, as it can be distributed through distribution networks directly into domestic drinking water installations.

The specialized literature demonstrates the current importance and utility of hydropower plants, which is why the accessibility of the developed theoretical system based on their use does not pose a problem. In Romania, hydropower is the most important source of electricity, contributing 36.3% to total energy consumption ("Types of Electrical Energy in Romania. What Is the Most Used in Our Country," 2023). Internationally, hydropower currently generates more electricity than all other renewable technologies combined and is expected to remain the largest source of renewable energy generation until the 2030s ("Hydropower - IEA," n.d.).

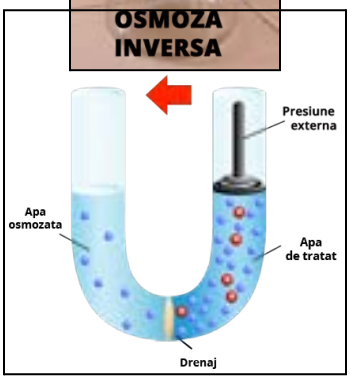
Annexes

Annex 1 - The Water Decantation Process

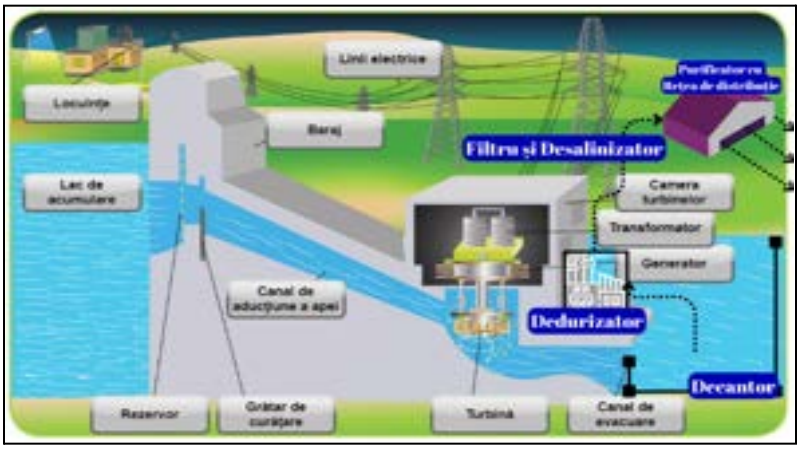


Annex 2 - The Water Softening Process (Xmasoft, 2015)

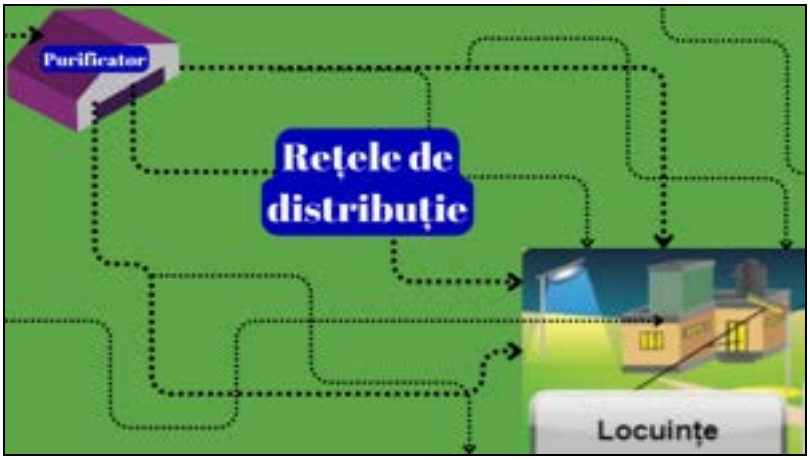
Annex 3 - The Wat cess



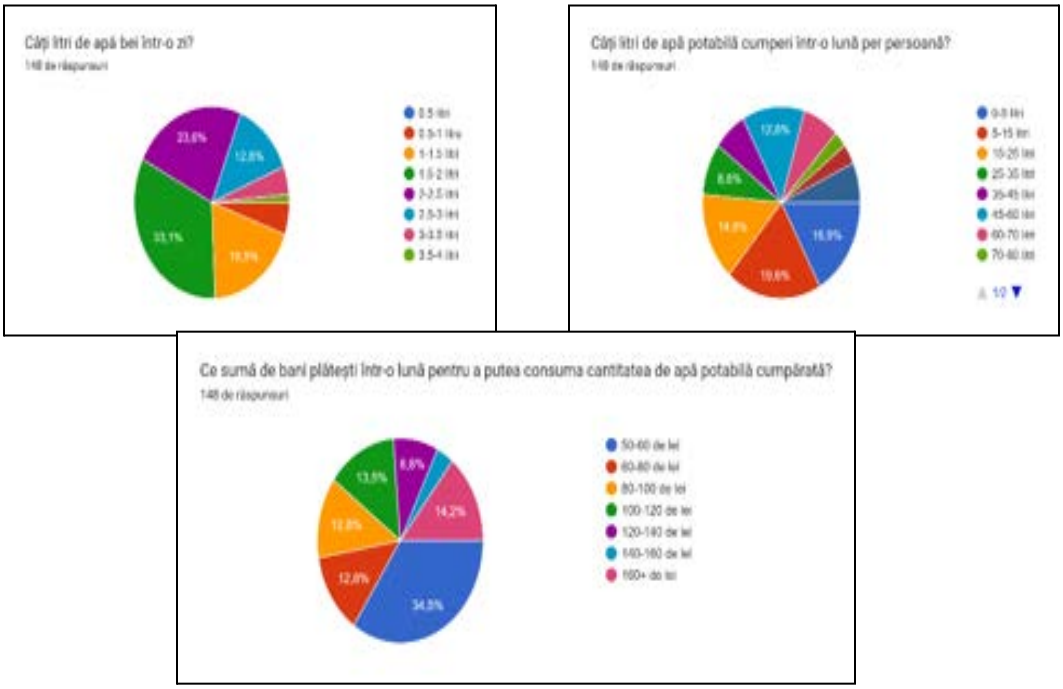
Annex 4 - The Water Desalination Process
(Reverse Osmosis - Reverse Osmosis Water Treatment Stations, n.d.)



Annex 5 - Theoretical System for the Use of Water Used by Hydropower Plants



Annex 6 - Theoretical System for the Distribution of Water Used by Hydropower Plants



Annexes 7, 8, and 9 - Personal Study

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Reigniting a Patient's Spark with Laughter: A Review on Shared Laughter and its Social Benefits in Palliative Care by Sanaa Bakhru

Abstract

Unfortunately, many seriously-ill patients struggle with loneliness and isolation when battling their sickness. However, there are certain ways to combat and alleviate these difficulties within palliative care. One such way that isn't sufficiently explored yet is through shared laughter. Exploring the psychological and social aspects of laughter reveals how it is vital in developing positive interpersonal relationships and improving emotional well-being. The purpose of this research paper is to determine how shared laughter and its social benefits can increase the quality of care for patients in palliative care. Moreover, examining current and future implementation of laughter-based activities in a palliative care setting can facilitate the powerful effects of laughter in creating a supportive and positive social environment for struggling patients.

Introduction

As of today, approximately 45% of all Americans suffer from at least one chronic disease, with numbers only growing across all disease categories (Ragupathi 2018). With an increasing number of people impacted by a serious illness, the demand for palliative care has grown as well. Palliative care is a specialized medical care for people living with a serious, sometimes terminal, illness including that of cancer or heart failure (NIH). In fact, as of 2020, more than 83% of hospitals had a palliative care team. (CAPC 2022). However, even with care systems in place, sickness can be a daunting task to navigate, often causing significant emotional and social hardships for patients and their loved ones. These social hardships include lack of communication, relationships, and comfort which results in increased stress and loneliness. With palliative care patients struggling with loneliness and stress, it's crucial that we explore various interventions and methods that will ensure the best quality of care for patients living with a serious illness. One such tool from positive psychology—the scientific study of human flourishing—that can be applied to help boost connection and wellbeing is shared laughter. The purpose of this research paper is to draw a connection between shared laughter and its potential social benefits in a palliative care environment through analyzing existing positive psychology and humor-based research. In this review paper, we will explore the positive psychology of shared laughter, analyze the current use of laughter between patients and caregivers in palliative care settings, and examine the ways of effectively implementing laughter-based activities into these environments.

Shared laughter

Laughter is everywhere and is arguably one of the best forms of psychological relief . Finding amusement and laughter in our daily life brings about numerous benefits whether that be uplifting mood, decreasing stress, or boosting our immunity (Yim 2016). While its emotional and

physical benefits are significant indeed, laughter also plays an important role in our social life. Humor—seen as the capacity to express or perceive what's funny—often acts as a stimulus for laughter between people. However, that doesn't mean laughter is always present in situations of humor, nor is humor necessary for laughter to occur (Ripoll & Casado 2010). Instead of solely focusing on what precedes laughter, like humor, it's also important to consider the significance of laughter itself. More specifically, shared laughter can play a crucial role in fostering positive relationships.

Shared laughter is characterized as simultaneous laughter between all individuals involved in an interaction (Algoe 2019). While the idea of people being able to simultaneously share laughter may seem unlikely to some, research has supported that people are able to share laughter when both are engaged in a positive social interaction. Several studies have found that people are highly attuned and responsive to others' positive emotions, specifically when there is the chance to form a new relationship with someone (Campos et al. 2015). Sharing laughter and amusement in life is one example of a positive interpersonal process. Recent research has conveyed shared laughter as a prominent indicator of a high-quality relationship (Algoe 2019). In general, people who experience frequent positive emotions in their relationships also report greater connection and commitment (Campos et al. 2015). It is also well established that people continuously seek out those who make them laugh. Thus, shared laughter between people signifies a sense of investment and ongoing interaction within a specific relationship (Wood & Niedenthal 2018).

Not only does the presence of shared laughter represent a positive relationship and social interaction but it also simultaneously contributes to building it. Within a social interaction, shared laughter can create a sense of affiliation and dissipate any sense of social unease or barriers that may have existed (Wood & Niedenthal 2018). One study reports that feelings of intimacy and safety between a romantic couple were more commonly experienced when they were sharing a laugh together rather than laughing alone (Algoe 2019). When two people share a moment of spontaneous laughter, they are showing a more vulnerable and open aspect of themselves with one another, contributing to this sense of closeness. Not only does laughter prevail in couple interactions, but it also serves a positive impact on multiple forms of relationships. For example, current research expresses that acquaintances—people who know each other but not at an intimate level—were able to relate and see a potential friend in each other when they shared laughter. (Algoe 2019). When two individuals are laughing and observing one another laughing, the positive emotions experienced can be amplified because oftentimes each person perceives that the other person gets them and sees things the same way. (Kurtz & Algoe 2017).

Another thought to consider when examining all the benefits of shared laughter is that happy relationships between people contribute to other positive outcomes in their life. For example, sharing laughter can help people develop better life habits and physical wellbeing as it contributes to better relationships. Research has shown that sharing laughter contributes to happy and positive relationships by increasing satisfaction, liking, and affiliation between partners

(Kurtz & Algoe 2017). With this idea established, further research has expressed that rewarding social relationships correlates with greater longevity and a better physical health (Fredrickson 2016). Other analyses showed that positive psychological constructs such as positive emotions and subjective well-being are associated with greater physical health results (Huffman et al. 2011). Sharing laughter itself is known to produce positive emotions and increase one's well-being and such constructs are often present in happy relationships as well. This all can provide an indirect link between how sharing laughter can help one's physical wellbeing. Furthermore, experiencing positive emotions in a relationship can help an individual cope and manage their anxiety and stresses in life better. One study that supports this idea showed that communication, using positive emotion and humor, between caregivers and family members could be effective coping strategies (Albert & Womble 2015). By drawing these connections together, it can be hypothesized that shared laughter and its social benefits contribute to various aspects of one's life including improved physical health and coping in stressful situations. Considering how helpful shared laughter may be in creating positive social relationships, it's essential to look at its use in different contexts like palliative care. We will explore how shared laughter is significant in these challenging, isolated situations that seriously-ill patients deal with frequently.

Shared Laughter in Palliative Care

In a palliative care medical setting where everything is centered around chronic and or terminal illness, there are often feelings of heightened anxiety, fear, crisis, and loneliness (Dean & Gregory 2004). Due to these particular experiences of loneliness and struggle, palliative care patients require more emotional dedication and time from their caregivers (Caro et al. 2017). Thus, the relationships patients form with their caregivers and other healthcare providers play a very crucial role in coping with their sickness (Caro et al. 2017). The role that shared laughter can have on strengthening relationships—through increasing safety, communication, and comfort—between patients and their caregivers is vital in ensuring their wellbeing. As mentioned earlier, humor can be present in instances of shared laughter, but shared laughter does not only occur in certain situations of humor. Shared laughter can often emerge just from connecting with others in a positive social interaction like a heartfelt conversation. Regardless, there are more studies done on positive interactions and humor than laughter in healthcare environments which is why many conclusions drawn on laughter will be done with the support of these types of studies.

Currently, while research has documented the value of laughter for patients, a majority of it has focused on terminal patients, rather than palliative care as a whole. In a study where 100 patients in palliative care units and residential hospices were interviewed, 76% of participants valued humor as important during their illness (Ridley et al. 2014). While the majority have come to consensus that humor—which often involves shared laughter—is valuable, current studies emphasize how terminally-ill patients practice and initiate it more than chronically-ill patients. Many patients in end-of-life care find ways to incorporate humor and laughter into their

lives as it helps distract them from the pain and negativity surrounding their impending deaths and focus on the positive (Showalter & Skobel 1996). One study examining humor in social interactions between nurses and terminally-ill patients found that humor was present in 85% of the 132 observed interactions and was initiated by patients 70% of the time, demonstrating that patients are seeking this interaction out with those around them (Adamle & Ludwick 2005). On the other hand, not many chronically-ill patients have been observed to seek out similar interactions with their caregivers. A study done on patients battling chronic illness—in this case, 105 women with a diagnosis of breast cancer—found that only 21% of them used humor or laughter interventions (Bennett & Lengacher 2006). Many barriers can explain their unwillingness to share laughter as dealing with a serious yet not fatal illness can lead to lots of anxiety and uncertainty of what's to come. In further analysis and review, we will transition from this idea that shared laughter is valuable to why it's crucial for all patients in palliative care, both terminally and chronically ill, to experience.

Effects of Shared Laughter: A Positive Psychology Approach

Based on current literature in the positive psychology and palliative care fields, shared laughter has helped many patients develop closer bonds with their caregivers. Positive emotions like amusement allow people to more easily socialize and have better social interactions (Waugh & Fredrickson, 2006). Through peer group activities that are a staple in laughter therapies, there is an amplified sense of rapport and understanding between patients and also with their caregivers (Tremayne & Sharma 2019). Moreover, taking part in laughter-inducing activities allows participants to revisit their playfulness and mindfulness, which are important for ill patients and their nurses (Tremayne & Sharma 2019). When considering the study of positive psychology, sharing laughter and relating to others may not only increase playfulness, but could also produce a certain level of optimism about their future and life in general. If chronically ill-patients share more laughter in the comfort of other people's company, they can feel more positive and happy in their situations. Having flexible and adaptive optimism has consistently been linked to better wellbeing, healthier life habits, and alleviating suffering and discomfort (Ripoll & Casado 2010). Thus, when chronically ill-patients share more laughter with others and open themselves up to its benefits, they can develop better physical, emotional, and social wellbeing. Having a better overall wellbeing is key when trying to manage or accept one's illness. Furthermore, it's important to realize that strong relationships are crucial in palliative care. The whole philosophy of palliative care is centered around human contact and showing care: humor including sharing laughter plays a significant role in establishing, enhancing, and maintaining trustworthy relationships in these environments (Dean & Gregory 2004).

Furthermore, research on positive emotions also supports how shared laughter can contribute to the humanization and comfort of patients in palliative care. Studies on positive emotions in healthcare found that when providers made the effort to understand the patient's situation and regard them as a person, they felt their feelings and thoughts were justified (Heyn et al. 2023). As discussed before, sharing a laugh can show that you "get" the other person and

can also bring out the “human” aspect in each other. Moreover, the 2019 study by Algoe mentioned in the previous section also supports how people feel more safe when laughing together with someone rather than alone (Algoe 2019). Thus, shared laughter can be seen as a way to help chronically-ill patients feel seen and allow them to develop stronger bonds with their caregivers and healthcare providers in palliative care. Additionally, sick patients described that non-verbal communications or behaviors were a predominant indicator of genuineness by their provider which was something they greatly appreciated (Heyn et al. 2023). Laughter, though vocal, is considered a non-verbal communication and when shared between people, it can express one's authenticity. Since genuinity in their providers is deeply valued by patients undergoing an illness, shared laughter will be a promising way to help deepen the patient-caregiver bond. Examining various positive emotions that patients value and experience throughout their medical care support how shared laughter can help palliative care patients socially in multiple ways.

Effects of Shared Laughter: A Humor Approach

On the other hand, research on humor in palliative care also supports this overarching theme that shared laughter can have many social benefits for seriously-ill patients. In general, the use of shared laughter and humor to break the tension and increase comfort can be significantly beneficial in a doctor-patient relationship. During a randomized study, 122 patients had their routine breast cancer screening where 66 patients received an examination with humorous intervention—where shared laughter was often involved—while the other 66 patients had a standard breast examination (Sartoretti et al. 2022). In the humor group, greater patient satisfaction was more widely expressed as patients remembered the name of the radiologist more often, appreciated talking with the radiologist, and felt that the radiologist was more empathetic than in the non humor group (Sartoretti et al. 2022). Considering the value of shared laughter and humor in medical examinations, it can further be applied in a palliative care setting as well. In light of this, an investigation from palliative/hospice nurse home visits with cancer patients and family caregivers found that humor was the most common positive emotion connection experienced overall (Terril et al. 2019). This marks humor, which often involves shared laughter, as an effective way to facilitate positive emotional connections and simultaneously strengthen relationships between patients and their caregivers in a palliative care setting. Another investigation conducted in an in-patient palliative care unit found that laughter and humor helped build relationships, decrease social distance, and humanize the experience a patient is going through (Gregory 2004 & 2005).

Overall, drawing from what we know about positive emotions and humor, sharing laughter is a great way to show a sick patient that you care as a healthcare provider and are attentive to their needs. If a caregiver or patient creates an opportunity to share a laugh with one another, it can lead to a closer relationship and allow for both of them to take their minds away from all the negativity that comes with illness even if it is for a short time (Dean & Gregory 2004).

Implementation of Shared Laughter in Palliative Care

As we explored how crucial laughter interventions can be in strengthening patients' social lives and overall quality of life, it is important to consider implementation in these palliative care environments. While some forms of laughter therapy focus on simulated laughter exercises such laughter yoga and meditation, we will be focusing more on the laughter interventions that are incited organically through positive connection and humor. If patients were to participate and engage in activities that make them feel more connected, comfortable, and happy in the presence of others, they can experience laughter. Not only in the context of positive social interactions but in activities where humor is present, people can also share laughter. There are countless activities where positive emotions and humor present themselves with some examples including playing group board games, dancing together, singing to songs, and more. Furthermore, if healthcare providers more frequently experience shared laughter—possibly in exchanges of humor or positive emotions—with their patients, it will create a more positive environment for them as well. This is supported by a study which enforced that healthcare staff who used lighthearted humor would attract others and tend to be the ones patients and other providers desired to work and be around (Dean & Gregory 2004). The same goes for patients as those who communicated using humor would have a greater number and variety of visitors (Dean and Gregory 2004).

That being said, multiple studies and research support the idea of healthcare professionals being trained in the use of humor and laughter (Sartoretti et al. 2022). In general, many healthcare professionals do not regard using laughter in their interactions with patients as unacceptable (Buiting et al. 2020). Laughter is seen as lighter than humor and can be more easily practiced and implemented by caregivers and health professionals (Buiting et al. 2020). However, many studies suggest that appreciation of humor is often subjective and that the context in which it occurs matters (Dean & Gregory 2004). This enforces that laughter and humor should regardless be used with caution in a manner that is not likely misunderstood as negative or inappropriate. Studies emphasize how clinicians should gain a basic understanding of the impact of laughter on patient communication, including how patients use laughter to build a connection with their healthcare providers and to encourage a respectful application of humor in clinical practice (Buiting et al. 2020). Additionally, since the majority of the studies incorporated are Western and coincide with the norms of Western culture, it is unclear if these ways of shared laughter interventions and its benefits apply to all populations around the world. The role of laughter in cultures needs to be further assessed to determine appropriateness and feasibility of it in other, non-Western, countries as well.

Conclusion

Ultimately, the main purpose of this literature review paper is to explore the connection between shared laughter and its social importance in maintaining the wellbeing of patients in palliative care. Looking through existing research and studies about humor and positive

psychology, it can be inferred that shared laughter can play a significant role in strengthening the relationships and bonds between patients and their caregivers. Implementation in a palliative care environment involves appropriate training to healthcare professionals on how to include laughter in their interactions as well as introducing more activities and situations where positive emotions and humor can be brought out. By improving trust and comfort within patient-caregiver relationships, patients may be able to better deal with the loneliness and stress of their situations. Every sick patient, including those who are chronically or terminally ill, deserves to experience the best quality of care as they bravely navigate through the stress and loneliness of their diagnoses. Sometimes what a sick patient needs the most is to share a good laugh.

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Scientific Progress' Inevitability: Through the Lens of Simultaneous Invention By Saron Getachew

Key words: simultaneous inventions, scientific progress inevitability, zeitgeist, independent duplicate invention, chance theory, invention, discovery

Abstract

In a journal article by Eugene Garfield (1980), the surveys by sociologists Warren Hagstrom and Jerry Gaston revealed that 72.6% and 64% of 1,718 U.S. and 203 scientists, respectively, reported at least one instance of simultaneous invention in their careers. Simultaneous inventions (SIs) are frequent phenomena occurring across different scientific disciplines and time periods. While opposing arguments attempt to establish SIs as probabilistic phenomena, literature suggests that their frequency coupled with the uniformity of the scientific processes preceding their production indicates that SIs are the result of external factors' influence: the zeitgeist or shared environmental exposures. Because of the consistent influence of environmental exposures in SIs and innovations, the unavoidable changes of scientists' surroundings stipulates new innovation and progress becomes inevitable. A systematic review of four studies examined how different types of environmental exposures influence innovation. The investigation focused on the independent variable of environmental factors, expressed in the form of prior knowledge, scientific methodologies employed in scientific investigations, and collaborative team dynamics. It was determined that the different facets of exposure all affect discovery and innovation. Overall, the importance of the zeitgeist within innovation, as demonstrated by secondary research and as corroborated by the data collection, indicates that the commonly occurring SIs are substantial tools to reveal that scientific development is bound to take place. SIs are manifestations of the inevitability of scientific advancement and the prevalence of the zeitgeist in SIs/innovations plays a big role in establishing the solidity of this notion.

Literature Review

In a personal interview with a professor emeritus of sociology, there was a discussion surrounding the philosophy of historicism–the idea that any historical event could be attributed to a predecessor coupled with the notion that socio-cultural change is inevitable. Through this worldview, Karl Marx and Georg Wilhelm Engel are only "midwives" of communism–merely speeding up and bringing about the inevitable birth of the socio-political and economic system. This philosophy on its own is highly debated, but it prompts curiosity about the inevitability of other aspects of humanity and reality. Does historicism extend beyond socio-cultural phenomena, spilling into science? Are scientists the midwives of scientific change, producing certain inventions or discoveries that are unavoidable consequences of knowledge accumulation? Due to the nature of scientific processes and inquiry, there are often duplicates in research, invention, or discovery from two or more scientists who had no contact with each other throughout the course

of their careers. This type of duplicate discovery or invention is the manifestation of scientific advancement's inevitability, falling under the term simultaneous invention (SI). For the purposes of this paper, independent duplicate inventions or multiples will be encompassed under the term of simultaneous invention regardless of the perceived simultaneity within each invention pair because the literature that will be discussed overpowering refers to them as such. An example of SI includes Newton and Leibniz's independently formulating calculus and the independent discovery of oxygen by Joseph Preistly and Carl Scheele (Gershgorn, 2018). When conducting such an investigation, the hypothesis of scientific progress inevitability was confirmed.

Although there is debate regarding the efficiency of utilizing simultaneous inventions to investigate scientific progress' inevitability, there is more compelling evidence leaning towards the notion that SIs are sufficient tools for such examination. Simultaneous inventions are encompassing and descriptive reflections of the general pattern of science due their frequency across various scientific disciplines as well as time periods, the underlying cause behind their occurrence is in agreement with the notion of scientific progress inevitability, and there is a consistent uniformity of the processes leading up to an SI. These components establish the solidity and importance of SIs in the larger set up of science as well as within the larger pattern of scientific progress in the form of discoveries and inventions. This means that the inevitability of scientific progress is directly demonstrated by the repetitive and established occurrence of simultaneous inventions.

The high frequency of simultaneous inventions, despite being hindered by the current patent law, reflects their prominence in science and suggests that their occurrence is an inherent consequence of scientific progress. Firstly, it is important to recognize that simultaneous inventions are generally frequent phenomena ingrained into the history of science. A list of 148 recorded simultaneous inventions were compiled in a journal article written by Professor Ogburn, specializing in sociology and statistics, and Thomas (1922), an undergraduate student at Columbia University. The Ogburn-Thomas list of multiples includes a wide range of inventions or discoveries in different scientific disciplines, grades, time periods, and degrees of importance (1922). The frequent emergence of circumstantially diverse simultaneous inventions, spanning across various scientific disciplines and exhibiting distinct characteristics, indicates that the phenomenon is consistently recurring within science–transcending the minutiae or specifics of individual circumstances surrounding each discovery. In essence, the universality of SIs in science as (exemplified in the Ogburn-Thomas list), occurring regardless of the specifics of SI innovations, highlights its systematic nature.

Although one form of SI frequency can be seen in its recurrence throughout history, another important aspect of the phenomena's frequency can be seen in the careers of regular scientists. Scientists frequently encounter multiple discoveries or inventions in the form of their research being anticipated by concurrently working colleagues. In a journal article by Eugene Garfield (1980), an expert in the study of broader science, there were discussions about the results of the 1971 survey by Warren Hagstrom, a sociologist at the University of Wisconsin. The survey was directed towards 1,718 U.S. academic research scientists, and when asked how many

times their research or work had been anticipated throughout their careers, 46.2% of the researchers reported one or two anticipations while 26.4% reported more than three. In a parallel 1971 survey by Jerry Gaston, a sociologist at Southern Illinois University, 203 high-energy physicists were asked the same question concerning research anticipations from throughout their careers, and 38% believed their research was anticipated once while 26% believed their research was anticipated more than once (1980). While journal articles–like that of Ogburn-Thomas' in 1922–investigate the frequency of historically significant or novel innovations, the surveys conducted by Gaston and Hagstrom reveal the pervasive nature of simultaneous inventions. Gaston and Hagstrom's findings, 76% and 64% of their participants reporting at least one instance of research anticipation/duplicates in their careers, uncover the presence of simultaneous inventions on smaller and more widespread scales of study–found even within the careers of regular scientists.

Although SIs are common throughout different corners of science, their full potential frequency and recognition is compromised by the flawed patent theory, the system that determines intellectual priority and credit. Firstly, the true hidden frequency of SIs is investigated in a journal article by computational historian Deryc Painter, economic geographer Frank van der Wouden, theoretical and historical biologist Manfred Laubichler, and interdisciplinary computational and mathematical researcher Hyeijin Youn (2020), where the method of novel persistent key framework was used on academic papers concerning evolutionary medicine published between 2007 and 2011 to identify simultaneous inventions and determine the extent to which they are independent of each other. After the systematic identification and analysis, 22 novel papers were identified and 19 of those papers were categorized as–for the first time–simultaneous independent inventions due to two or more papers introducing new concepts into evolutionary medicine. For example, a single case of SI included the independent publication of five novel papers in 2009 and each paper similarly introduced the idea of triglycerides having a complex role in the field of evolutionary medicine (2020). The fact that these instances of SIs went previously unrecorded and unnoticed until actively sought out indicates that the current documentation of simultaneous inventions fails to capture the true scale and commonality of the phenomena. This implies that the actual frequency of SIs exceeds previous estimations and listings, even if the regular occurrences of SIs vary in terms of prominence and linkage to one another.

One significant factor contributing to the underrepresentation of SIs in the phenomena's reports is their perceived undervaluation and neglect in the current reward system of science. In a journal article by renowned sociologist Robert K. Merton (1963), it is stated the qualities that are valued in the patent system include originality and utility. Due to this structure of credit, simultaneous inventions are considered redundant and become overlooked as they may represent a waste of effort and funding by proposing the same discovery or invention more than once (1963). Patent theory prioritizes solely original and individually created innovations, cultivating the view that SIs are useless endeavors consuming valuable resources. This viewpoint hinders both the recognition and reports of SIs, and it discourages scientists from pursuing research that

has higher chances of resulting in simultaneous invention. Consequently, due to this widespread understanding of SIs as useless, there are few documentations and records of SIs–especially in investigations preceding Merton's 1963 paper.

Furthermore, the current patent law also fosters conditions that actively inhibit the potential frequency of SIs and intentionally prevents the production of SIs. Mark Lemely (2013), a professor of law at Stanford Law school, investigated the limiting and skewed nature of patent theory. First, Lemely addressed the patent laws' subscription to the myth of the sole inventor. Patent theory assumes that an invention or discovery is made by only one scientist or professional and gives recognition to the first person to apply for that particular innovation. A large portion of patents are dismissed when the innovation has already been recognized, even when the time gap is very short. Additionally, Lemely discussed the underlying principles of the patent law: prospect, commercialization, and disclosure theories–all theories being contributors to the distorted/ineffective nature of patent law and all theories preventing SIs from occurring. Prospect theory gives companies early patents so they can control and own any research and development concerning the contents of that patent. Commercialization theory grants patents seeking the encouragement of product development–investments and commercialization of innovations–over the encouragement of progress. Finally, disclosure theory includes a detailed description of inventions and has prompted concerns of detail secrecy. The Federal Circuit–in part one of the patent laws–had repeatedly allowed vague and untelling disclosures at the forefront of patents when disclosures are supposed to publicly share enough information to help peer efforts toward scientific progress. In essence, Lemely argues that, while the patent law seeks to incentivize progress and the foster of innovations–such as through patent races to spur friendly competition–, it is ultimately unsuccessful due to its tendency to grant exclusive rights to one person, thereby coming in interference with the crediting of multiple innovators. Not to mention, the system's prioritization of profit-driven ideals undermines the spread, recognition, and appreciation of knowledge (2013). Given the value put upon originality and individuality by the legal system–seen in the myth of the sole creator and prospect theory–, simultaneous inventions inherently defy both the values of originality and individuality. Consequently, SIs are generally unwelcome and regarded as hindrances, impeding researchers and investigators from accurately assessing their true frequency due to the compromising influence of external systems. This impediment by the scientific credit system further suggests that SIs are more common than currently acknowledged.

Overall, the circumstantial diversity and frequency of SIs are initially established by the Ogburn-Thomas paper listings, and are reinforced by recognizing that SIs are not confined to isolated historical incidents, but rather are integral and commonplace phenomena within scientific inquiry, discovery, and invention. The 2020 study by Painter et al. further revealed the unseen and hidden case of SIs, uncovering their downplayed commonality in science. SI's potential irregularity in frequency can be attributed to the current patent system that is filled with misplaced values and flawed groundwork that prevents recognition and production of SIs, suggesting that SIs are naturally more common than previously acknowledged.

The high frequency of SIs indicates the existence of an underlying cause behind their occurrence. This underlying agent can be the driving force of the innovation and, therefore, show SIs to be inherent consequences of science. The prevalence of multiple discoveries in science indicates a shared influence amongst scientists, an agent–the driving force previously mentioned–compelling them to adhere to similar processes and pursue similar paths. This common factor can lead multiple scientists to follow the same trail of inquiry, resulting in an occurrence of SI when influenced in the same manner. One impactful common factor behind the occurrence of SIs is a similar or shared environmental predisposition. Ogburn and Thomas (1922), in the study previously mentioned, emphasized the recurring pattern of multiples across different circumstances–such as disciplines and time periods–as indicative of an underlying cause engraved in the fabric of science that caused the occurrence of SIs, pointing towards the influence of shared environmental factors (1922). This observed frequency of SIs in different circumstances reinforces the prominence of the phenomena, but–more importantly–the paper proposes the existence of a common influential cause uniting together and present within the different circumstances, going beyond just contextual-variability. In other words, the Ogburn-Thomas paper began to focus on the patterns in which SIs develop and not only on the conceptual patterns of SI innovations themselves. This perspective allows the patterns of innovations to be linked to common causes like similar backgrounds or similar influences in scientists, that lead them to create the same work or to come to the same conclusions.

In Malcom Gladwell's (2008) *The New Yorker* article, former Microsoft employee and scientist Dr. Nathan Mythrovold discussed the link between innovation and contextual factors by looking at how the goal of his Intellectual Ventures company was to create an optimal environment to cultivate insight/ideas. In Intellectual Ventures, experts from different disciplines and backgrounds had meetings on various topics to produce new, unique, patentable ideas. Intellectual Ventures filed 500 yearly patents, when the goal was 100, and licensed off 80 million dollars worth of patents as well. The success of Intellectual Ventures can be attributed to the participants' utilization of environmental factors/backgrounds to create new innovations and applications (2008). This case of insight orchestration by Intellectual Ventures reinforces the notion that seemingly passive, underlying, or unseen agents in the process of innovation, specifically environmental influences, can become the drivers in the creation of a new product or idea. The success of the Intellectual Ventures is a testament to the importance of a scientist's environmental influence on their work and suggests that, because innovations are generally the applications of someone's environment or background, simultaneous inventions are the application of shared environmental exposures.

The prevalence of SIs in all types of inquiry can also be demonstrated by their documented occurrence within science and technology since the prehistoric era. In Jenning and Smallwood's (2018) comparison of blade technology between the prehistoric Clovis culture and Toyah culture of the North American Southern Plains, an evolutionary approach on archeological evidence revealed the convergence of the two populations' histories. Blade technology was a defining characteristic in both the Clovis era dating back to 113,100-12,700 years BP and the

Toyah era dating back to 650-300 years BP. Although the development of the Clovis and Toyah blades were separated by thousands of years without a direct connection to one another, there were similarities in the blade as a final product as well as similarities in the processes leading up to its production. Both Clovis and Toyah blades had specialized flakes with parallel sides and lengths twice the units of the width. Both populations produced the technology using core-reduction techniques that correlated to their hunter-gatherer mobility strategies and used homogeneous nodules of stone like chert or obsidian to make the blades (2018). The similarities of the final product and the processes leading up to the blade technology made by the independent Clovis and Toyah peoples reveals that the phenomena of simultaneous invention transcends academic scientific settings, establishing the phenomenon's presence across various types of informal procedural advancements. This indicates that SIs are an inherent consequence of scientific and technological inquiry.

The establishment of the frequency of duplicate independent inventions raises questions about the theories that explain their occurrence in the first place, questions about the opposing theories of zeitgeist and chance. Although the theory of chance plays a role in the occurrence of multiples, the strongest and most influential agent driving the frequent occurrence of simultaneous inventions is shared environmental factors amongst scientists, the zeitgeist. Dr. Idhe (1948), an associate professor of chemistry and integrated liberal studies at the University of Wisconsin-Madison, initially highlights the importance of intellectual ability of an individual as well as the necessity of an idea or tool to bring about an innovation, but then, he emphasizes that– without the correct background or scientific preparations–pure intellect and necessity are directionless and virtually useless. Dr. Idhe had compared the different elements that contribute towards the creation of a scientific and culturological period ready for a certain invention: above average intellect of an individual scientist, the presence of sufficient accumulation of knowledge, and a problem that attracts collective efforts. Necessity, which only creates a concentration of scientific attention towards a certain problem, and genius, futile without applications of the intellect, cannot produce a discovery or invention on their own. For example, the creation of the spectroscope was not single handedly brought about by the need to study celestial objects chemically (1948). Firstly, the importance of intellect and a single genius is greatly diminished by the occurrence of multiple inventor SIs and, because the genius needs to be coupled with other environmental exposures, it is clear that even the role of intellect in innovation and in SIs is dependent on the zeitgeist. Additionally, because pure socio-cultural necessity and individual intellect are insufficient in driving innovation and the existence of simultaneous inventions weakens the idea of a single intellectual ability's importance in scientific progress, the most compelling agent in the creation of a certain solution, discovery, or invention points toward a different factor, the accumulation of foundational knowledge. For example, the 1948 article also discusses how John Dalton's atomic theory had roots in the philosophical ideas of the Ancient Greeks, but his theory could only be established and fully developed after chemistry and experimentation had supported the ideas in the 19th century. It was in the 19th century that the law of conservation of energy, ideas about the different elements, analytical balance, laws

concerning gasses, and the law of definite proportions were either established or becoming widely accepted. Dalton's theory had built upon these ideas and Dalton could not have produced his final theory without the presence of the chemical principles established before his time (1948). The idea that theoretical scientific advancements directly build upon pre-existing knowledge indicates the importance of the zeitgeist or environmental exposure of scientists in producing new insights. Amongst the different elements that may potentially create these scientific progresses, informational or environmental exposure of a scientist to foundational ideas in their respective fields is more important than the intellectual ability of an individual or pure socio-scientific pressures in terms of bringing about scientific advancements.

Delving further into the effects of prior knowledge and environmental predispositions on innovation, *The New Yorker* article previously mentioned discussed the environmental exposures to which Newton and Lebniz were subjects to, the creators of the simultaneous invention of calculus, and how the exposures stemmed from Newton and Leibniz existing in the same intellectual milieu as well as them applying the same pre-existing concepts of mathematics. Before Newton and Lebniz discovered the principles of calculus, the mathematicians Pascal, Decartes, and John Wallis had established the foundations necessary for calculus to develop. Newton's teacher, Isaac Barrow, also had in depth knowledge of Italian mathematicians Torricelli and Cavalieri's work. Italian Leibniz had close relations with Henry Oldenburg, accustomed to the work of English mathematicians. Additionally, the simultaneous invention of the telephone, created by Bell and Grey, arose from the pressing need to address the technological challenge of transmitting multiple messages simultaneously along a telegraph wire. Not to mention, both Bell and Grey had read the work of Philipp Reis, who had come close to assembling the telephone himself (Gladwell, 2008). These examples of simultaneous inventions and their innovators belonging to similar knowledge pools demonstrate how innovators build upon existing knowledge instead of producing entirely novel concepts. Inventors or discoverers use their unique skill set and intellect to derive unique discoveries from fragments of information preceding them, much like Bell or Grey had access and used the pivotal works of Reis. Due to the cumulative nature of discovery and invention, disciplinary and intellectual exposures are bound to influence a scientist's invention. It is when scientists of similar levels of skill uncover new ideas from older pieces of information they both had access to that simultaneous inventions occur.

Delving deeper into the influence of collective knowledge pools on innovations and SIs, in a study conducted by Painter et. al (2020), there is an emphasis on the importance of shared collective knowledge pools found in simultaneous inventions. In 2008, three independent novel publications simultaneously introduced chromatin, a condensed DNA in eukaryotes, into the field of evolutionary medicine. The three papers did not have co-authors in common, but they did have references in common. Furthermore, two of the papers used the model organism *drosophila melanogaster* in their respective studies (2020). Because all three papers had utilized the same information in their research and were exposed to the same specific body of knowledge, they produced the same connection between chromatin and evolutionary medicine. This instance

of SI further reinforces the importance of zeitgeist or environmental factors in the occurrence of simultaneous inventions.

In Jennings and Smallwood's (2018) journal article, the influence of physical environmental factors is emphasized in the multiple independent invention of blade technology by the Clovis and Toyah peoples. The characteristics of the blades, both in the Clovis and Toyah eras, were influenced by the environmental conditions and the human inhabitants' adaptations to their evolving environments. The Clovis and Toyah periods were both subject to harsh transitions in environmental conditions. The Clovis period, near the end of the North American Ice Age, endured a complex change in the environment and was plagued by shifting temperatures, precipitation patterns, seasonal fluctuations, mass extinctions as well as biotic reorganization with 35 genera of animals like the mammoth close to extinction, and changing availability of resources. The conditions of the time period led the inhabitants to change their patterns of subsistence, mobility, and develop their hunting strategies. The inhabitants of the Clovis era had diets that depended on the hunting of large game like mammoth. Because mammoth herds were becoming spatially unpredictable, the hunters adapted their mobility strategies to take advantage of the game that was available to them. The change in mobility directly affected the tools they used and led to the development of their blades. On the other hand, during the period of the Toyah, there was a significant change in the climate with lands increasing in moisture, woodlands expanding quickly, vegetation changing, and bison reappearing in patchy and unpredictable herds. The inhabitants of the North American Southern Plains in this era also had diets largely consisting of large game, specifically bison. 83% of archaeological evidence from the Toyah period had mentioned or referenced bison, showing the importance of the animal to the human inhabitants. Because the bison had unpredictable grazing patterns, the Toyah people had to adjust their hunting strategies and, similar to the hunter-gatherers of the Clovis period, had to adjust the tools/blades they used in hunting (2018). The Clovis and Toyah peoples' need for technological advancement, stemming from their rapidly changing physical environment and shifting food patterns, directly influenced duplicate development of their blade technologies. This instance of multiple invention reveals the significance of deterministic influence of the zeitgeist influences, emphasizing the pivotal role of environmental exposures like necessity in driving scientific and technological developments, even in contexts where clear formal scientific environments are absent. The significance of the zeitgeist and environmental factors–like socio-cultural necessity and the accumulation of foundational knowledge–in both duplicate and general innovations is evidentially overpowering and deterministic.

The theory opposing the zeitgeist, chance theory, completely rejects the deterministic role of environmental exposure in producing simultaneous invention. It claims that simultaneous inventions are purely coincidental and unpredictable probabilistic phenomena. The Poisson distribution–depicting SIs as random and scattered without a common link to science tying them together–became the most prominent support and foundation of the chance theory, but after reevaluation it became considered an inefficient explanation of multiples and, in turn, the evidential basis of the chance theory was invalidated. In information scientist Eunegene

Garfield's 1980 journal article, the Poisson statistical distribution or "Ripe apple model", proposed by historian of science Derek Price and supported by psychologist Dean Simonton, is used to explain multiples as largely probabilistic phenomena. Garfield explained how Price had created a model in which there are 1000 apples, representing possible innovation, in a tree and 1000 blindfolded men, representing scientists. Each man can reach up the apple tree with the chances of one man getting a single apple or two men getting the same apple. The predictions of the Poisson model were 37% of the scientists having single apples and 63% engaging in duplicate discovery. When this model was implemented on Merton and Elinor Barber's list of 264 SIs by Simonton, there were mean values 0.8 to 1.6 and the value of 1.4 was in highest agreement to the list of SIs. This means, there was a general trend of 41% of the discoveries being SIs and 35% being unique. After a statistical analysis of the Ogburn-Thomas SI list, 1.2 was the agreeing mean. Simonton argues, supported by Price's model and Schmoklers probabilistic arguments, that both the heroic/genius theory and social determinism theories (zeitgeist) of SIs are unsupported by the statistical analysis, but the chance theory is (1980). The Ripe Apple model presented a purely probabilistic phenomenon in which, devoid of external influences deeply impacting the process leading up to innovation, scientists have a certain likelihood of independently and coincidentally arriving at the idea or discovery. Because of this clear dissociation between SIs and environmental factors, the credibility of the zeitgeist's influence on innovation is significantly weakened.

However, in their 1983 journal article, Dr. Augustine Brannigan and Dr. Richard Wanner argue that the Poisson distribution, the major supporter of the chance theory, is not a sufficient statistical description of simultaneous inventions. One of the major problems of the Poisson distribution, which uses the grade element of multiples (how many innovators there are in a SI), is the assumption of an inverse relationship between the probability of discovery and number of scientists, when historical data disproves the existence of an inverse relationship altogether. Additionally, another problem within the model is the decline of alignment between the Poisson distribution and the true distribution of historic SIs overtime. Furthermore, the Poisson distribution model leaves out key contextual factors such as the variation of grades of multiples in different scientific disciplines (1980). Although the Poisson distribution indicates that SIs are at least partially probabilistic phenomena, the model lacks alignment between its results/predictions and historical evidence. Not to mention, the model excludes important contextual factors necessary in understanding SIs. These issues in the distribution significantly weaken any credibility and accuracy of its results—the result being the probabilistic occurrence of SIs. It is due to this inadequacy that the Poisson distribution can no longer be sufficient evidence for the probabilistic nature of SIs, further discarding the chance theory and no longer providing evidential argument against the zeitgeist.

The zeitgeist theory, on top of being a more historically and evidently sufficient explanation of SIs, is more statistically accurate when compared to the chance theory. In Brannigan and Wanner's (1983) journal article that was previously mentioned, seven different statistical representations of SIs were employed in order to test the accuracy of different SI

theories' predictions. The paper utilized the system analysis of Generalized Linear Interactive Modeling on a list of 1,235 SIs. The study examined how the grades and time intervals of multiples changed depending upon the time period (century), scientific discipline, the nature of an SI (empirical or theoretical), the type of SI (discovery or invention), and nationality of the innovators. The statistical analysis showed a gradual decline in the grade of multiples and a decline in the time intervals between the inventions within an SI. The communication theory of multiples, which states that multiples are the result of poor communication between scientists and duplication of research declined when scientific establishments gradually emerged, predicted a decline in both the grade and time intervals of multiples. The chance theory predicted no change in both time interval and grade of SIs. The zeitgeist predicted an increase in grade, but a decrease in time interval overtime. The analysis supports the zeitgeist, which can be compatible with the communication theory, and discredits the chance theory (1983). When another significantly more sound statistical model, one presented by Brannigan and Wanner, was employed on a collection of SIs–fixing the flaws of the Poisson distribution–, the zeitgeist was supported significantly more than the chance theory. As opposed to the insufficient Poisson Distribution, the statistically accurate communication theory can be compatible with the zeitgeist theory and not in argument against it, but it is not compatible with the chance theory because the chance theory denounces all contextual patterns determining the occurrence of SIs. When comparing the two explanations of SIs' occurrence, the zeitgeist and the chance theories, the zeitgeist is significantly more sound statistically and historically.

Another aspect of simultaneous inventions that further establishes SIs as valid descriptors of patterns within broader science, specifically the pattern of deterministic progress, is the uniformity of individual processes that lead up to SIs. These methodological or procedural aspects leading up to simultaneous inventions are formulaic, indicating yet another form of zeitgeist or socio-culturally deterministic tendencies in science. The scientific method, present in simultaneous inventions as well as in professional scientific procedures, is the uniform formula behind scientific investigation. The factors that are present in and driving the scientific method are the same agents that are responsible for simultaneous inventions when commonly shared amongst independent people or groups. In the lecture notes from the "Phil 6200 Philosophy of Science" course at Loyola Marymount University (Almanza, n.d.), the history and structure of scientific deduction is examined. The scientific method, originally developed by Newton, Galileo, and Kepler, consists of a cycle of observation, hypothesis, experimentation, analysis, peer review, and skepticism. This iterative cycle seeks to create a cumulative body of knowledge and has become the basis of modern science and scientific method. The overarching objective of the scientific method is to systematically address complex problems through a logical formula of deduction (n.d.). The consistent and repetitive cycle in which scientists gather data and test information, existing since the earliest "genius" scientists like Newton and Galileo, shows the formulaic and–therefore–systematic nature of innovation and SIs. In an article from the UC Berkeley Museum of Paleontology, the motivations driving scientific inquiry are problem solving, necessity, technological development, and decision making. The framework of science

consists of an iterative cycle of these motivations becoming applications through the use of the scientific method. For example, new information concerning the nature of DNA structure allows the development of fingerprinting, genetically engineered crops, and tests for genetic diseases. The new technologies of DNA copying and sequencing allows a better understanding of evolutionary relationships between organisms. The potential of engineering drug-producing microorganisms as treatment for diseases incentivizes researchers to conduct more investigations in the microbe field of study ("Benefits of Science," n.d.). This recurring sequence of motivation, research, and application implies a consistent and uniform investigative and problem solving approach among scientists. Given the established importance of shared environments in the occurrence of SIs, this standardization within the scientific method can be seen as a different facet of shared factors amongst researchers, specifically centered on the common processes leading up to an innovation. Consequently, the collective process preceding a discovery or invention can yield influence over the emergence of SIs, parallel to how the environmental zeitgeist fosters duplicate inventions. However, instead of focusing on the role of shared background and pre-existing knowledge, the uniformity of the scientific method emphasizes the similarities in deduction and problem solving approaches–a distinct aspect of the zeitgeist.

The uniformity of processes towards innovations further reinforce the connection between science or scientific method and multiple independent discoveries. In Stokes' (1986) Deakin University study "Reason In the Zeitgeist", he investigates the logical processes that lead to SIs. In the simultaneous invention of the double Helical model of deoxyribonucleic acid DNA structure (SBS: side-by-side structure), which was an alternative model of the Watson-Crick DNA, discovered by G. A Rodley's group at University of Canterbury in Christchurch, New Zealand and Sasisekharan's group at the Indian Institute of Science of Bangalore in 1976. The thought processes and approaches to the discovery of the SBS model was largely consistent in both the Sasisekharan and Rodely's groups. For example, both groups wanted to solve the problem created by the original Watson-Crick model of DNA that limited vertical or horizontal separation of a strand of DNA and create topological independence of two strands/helices. They had the same procedural restraint of adhering to the original Watson-Crick model as much as possible due to the importance of other aspects of the original model (1986). This indepth exploration and investigation of the SBS DNA simultaneous invention revealed the procedural commonalities of the two parties of innovators. The two parties both had to work within similar approach constraints, and they followed similar processes, leading them to arrive at identical ideas. The instance of simultaneous invention revealed a causal relationship between the procedural approach or educational background of two parties of scientists and the uniformity of their products due to their analogous scientific methodologies.

Creativity, amongst the initial steps in the process of invention or discovery, is in further support of the consistency seen within the scientific process. The seemingly chaotic, disordered, and unpredictable nature of creativity might suggest the lack of discernible patterns in science, but environmental influences can impart a degree of uniformity to these creative scientific processes, specifically in similar contexts and types of innovation. In psychologist Dean

Simonton's (2021) paper on creativity, creativity in an invention or discovery is defined by a combinatorial of three parameters. The three combinatorial parameters, which are deduced strictly based on the problem solving stage of an innovation, are the utility of an invention (u), the initial probability or the probability of a combination/invention being generated during the first session of inquiry (p), and the prior knowledge of the inventor or discoverer (v). Depending upon the combination of the parameters, there can be eight classifications of a combination or innovation. Although the eight classifications may appear to be solely dependent on each scientist's unique circumstances or appear random, the nature of each innovation is inherently tied to the creativity of the scientist involved. Simonton discussed how the creativity, both in type, extent, and depth, of a scientist preceding a process of scientific process is influenced by environmental factors stemming from other non-scientific aspects of the scientists' lives. For example, diversified circumstances in childhood or adolescence can result in higher chances for creativity, leading to a higher form of originality and surprise (related to the parameters of prior knowledge and initial probability) in scientific endeavors. Additionally, other environmentally influenced personality characteristics play a role in creativity. For example, characteristics such as Openness to Experience from the Five Factor Model, forms of cognitive disinhibition, and psychopathology (on a subclinical scale) are all associated with creativity and creative accomplishment (2021). Although the variety and seeming randomness of the creativity combinatorics may suggest that scientific processes preceding innovations are generally chance-driven and unpredictable, the drivers of what type of creativity a scientist uses and what the creative nature of innovation is can be heavily influenced by the background and environment of a scientists–both during the process of innovation and during the career/life of the scientist preceding the innovation. The fact that there can be a systematic categorization of similar types of creative processes rids the notion of disorder and complete randomness from creativity within scientific innovation. Additionally, the type of combinatorial creativity a scientist uses or exhibits being heavily impacted by the environmental factors further reinforces the idea that the zeitgeist influence is present in all aspects of invention and discovery.

A setting in which this idea of systematically shaped creativity and scientific processes was investigated in legal scholar and practitioner Amy Landers' (2010) journal article on the ordinary creativity in patent law, the journal article discussing the collected data of biological anthropologist Robin Dunbar. Dunbar had collected data from four different biology laboratories investigating different aspects of scientists' work. Dunbar found that, in the case of inconsistent experimental results becoming a roadblock, the scientists made changes in their mental approach and created new ideas or conceptualized new pieces of knowledge when they came in contact with their colleagues. Additionally, Dunbar found that the scientists' abilities to solve over 465 challenging problems was notably dependent on the diversity of the social structure and intellect of the scientists in the labs (2010). When the similar environmental influences-in the form of similar social settings–were duplicated and present in the different laboratories, duplicated also were the types of creativity and scientific processes employed by the scientists. When scientist's performance in the experiments was measured by the speed of solving problems and the

individual success rate of their ideas, there was a significant reliance of their performance on their social surroundings, reinforcing the notion that the zeitgeist, the deterministic influence of environmental factors, is present in the processes leading up to a discovery or invention. The zeitgeist is not only present within the patterns of SI's nature of occurrence or the contents of the innovation itself, but present also in the way the innovation is developed and in the systematic nature of scientific inquiry. It is the uniformity of scientific processes and the systematic development of scientific creativity that further highlights the inevitable aspect of scientific progress–explored through simultaneous inventions, which are caused by the duplications of the processes of inquiry coupled with similar environmental predispositions.

Overall, simultaneous inventions are inherent consequences of science, and they are ingrained into the history, production, and mechanisms of scientific inquiry, discovery, or invention. Although factors like the patent system dictating scientific credit compromise and decrease the documentation and acknowledgment of the phenomena, SIs are widespread and reflective of the underlying inevitability of scientific progress. Through investigations into their occurrence and the factors influencing them, such as environmental exposures and procedural aspects of innovation, simultaneous inventions reveal the systematic and formulaic nature of scientific advancement. Their frequency, coupled with their consistent occurrence being driven by environmental factors and procedural aspects, solidifies their role as sufficient tools for investigating the inevitability of scientific progress. Beyond mere academic inquiry, understanding simultaneous inventions enriches people's comprehension of the relationship between science, scientists, and the trajectory of knowledge advancement, which sheds light on the fundamental dynamics that are driving scientific evolution and the role of scientists as agents and midwives of change.

Data Collection and Methods

Systematic review was used to examine how different types of environmental exposures influence innovation. There was an investigation of four selected studies that focused on the independent variable of environmental factors, specifically expressed in the form of prior knowledge, diverse scientific methodologies employed in scientific investigations, and diverse collaborative team dynamics in scientific settings. The first study, titled "Exploring Uncharted Territory: Knowledge Search Processes in the Origination of Outlier Innovation", utilized interview and patent data to examine if novel or outlier inventions are caused by one or more of the following: 1) long idea search paths, 2) differences in processes of scientific deduction and induction, and/or 3) distant re-combination of pre-existing knowledge fragments (Kneeland et al, 2020). In Professur Dunbar's study (1995), titled "How Scientists Really Reason: Scientific Reasoning in Real-World Laboratories", the natural scientific process towards innovation was simulated in the "vivo" part of the study, tasking scientists with rediscovery. The second part of Dunbar's publication involved a year-long observational (or vitro) study of four major molecular biology laboratories, documenting the cognitive and social aspects of their scientific processes. Thirdly, Dr. Ganguli's study (2020) titled "The Paper Trail of Knowledge Spillovers: Evidence

from Patent Interferences" compiled data from 1,329 patent interference decisions, which are representatives of SIs in patent law, between 1998 and 2014 to create a database, applying geographic matching to analyze the spatial localizations or proximity of each innovator in a patent interference case. Lastly, in the source titled "Prior Knowledge and the Discovery of Entrepreneurial Opportunities", Dr. Shane conducted interviews and documented eight different entrepreneurial businesses that had exploited the MIT technological invention of three-dimensional printing. The study focused on exploring the influential role of prior and specialized knowledge in the process of entrepreneurial opportunity recognition and business creation.

Results and Analysis

Figure 1 – Environmental/External Exposure: Effect of Prior Knowledge and Background on Discovery

Source A: *"Exploring Uncharted Territory: Knowledge Search Processes in the Origination of Outlier Innovation"*	Source B: *"How Scientists Really Reason: Scientific Reasoning in Real-World Laboratories"*	Source C: "The Paper Trail of Knowledge Spillovers: Evidence from Patent Interferences"	Source D: *"Prior Knowledge and the Discovery of Entrepreneurial Opportunities"*
Long Search: - A novel innovation to scientists (outlier patents) may not be novel in the eyes of the innovator, but the innovation may have occurred as a recombination of distant pieces of information. - Creation of "Spider Goats": combination of biotechnology and information. - Johani Stoni's fluorescence device: combining exposures from his father's work.	- Vitro: Initial mindset or initial goals (prior knowledge) influenced scientists' work. - Vivo: - Different classes of analogies (like local and distant) in scientific communications, taken from a scientist's personal toolbox, were crucial in discussions→4 to 22 various analogies used in any given discussion. - Experienced scientists were less likely to maintain a rigid hypothesis and to be	- Interference example relating to haptics and the lens: opposing parties founded the invention two years apart; both located in Irvine, California; very similar knowledge inputs about corona discharge problem. - Interfering cases are 1.4 to 4 times more likely to live in the same area than non-interfering cases: 12-14% of interfering inventor pairs are	- Individuals with specialized knowledge (idiosyncratic prior knowledge) found it easier to quickly recognize opportunities in their respective domains and assess its feasibility and potential impact. - Contextual understanding was important for each separate business to understand how to target their specific

	subjects of confirmation and falsification bias.	within 161 km; 5-8% of control inventor pairs.	audience using the 3D printing device.

As expected by the hypothesis and the zeitgeist, all four studies indicate that a scientist or professional's pre-exposed knowledge significantly plays a significant role in the production and details surrounding inventions or discoveries. Source A revealed the importance of a specific scientist's unique toolbox of information in their novel innovations. Prior knowledge or informational exposures are key in the process in which a scientist pieces together ideas because scientists may often combine distant pieces of information to create new ideas or products that colleagues might not have had access to without the right informational/environmental exposure. Source B discussed how greater flexibility of a scientist's initial mindset and hypothesis–adopted before starting an experiment–led to a higher success rate in their given tasks. Additionally, source B documented how the hypothesis, mindsets, and biases of the scientists in the laboratories observed changes based upon the years of prior experience. In source C, the geographical proximity of innovators is linked to interference cases and simultaneous inventions with innovators of interference cases significantly more likely to live in the same area than non-interference cases. The last source demonstrated how a party's recognition of entrepreneurial opportunities and its facets heavily relied on the entrepreneurs specialized knowledge and previous exposure. Additionally, source D, focusing on how businesses used an invention, demonstrated the importance of contextualized knowledge by highlighting how eight businesses' had their various aspects of marketing, utilization of the innovation, and audience engagement involving each participants' previous experiences.

Figure 2 – Environmental/External Exposure: Effect of Various Types of Scientific Processes on Discovery

Source A: *"Exploring Uncharted Territory: Knowledge Search Processes in the Origination of Outlier Innovation"*	Source B: *"How Scientists Really Reason: Scientific Reasoning in Real-World Laboratories"*	Source C: "The Paper Trail of Knowledge Spillovers: Evidence from Patent Interferences"	Source D: *"Prior Knowledge and the Discovery of Entrepreneurial Opportunities"*
- Scientific reasoning (deduction & induction) used by scientists to predict, identify, and follow through with a valuable endeavor: finding	- Vitro: - Scientists following ridgid methods of rediscovery and		- All eight entrepreneurs→utilized recognition (closely related to what the individuals had already

where a solution/answer could be found and distant recombination. - Prediction of nanotubes conductivity catalyzing a new generation of chip technology. - Patent for using water stabilized antimicrobial organosilanes: followed an unusual approach of fundamental chemistry. - Interviews with separate innovators Jason Gestwicki and James Murto revealed: different approaches in their inventions/methods than colleagues.	pursuing unaltered hypotheses/goals did not succeed in fulfilling their task of discovery. - Scientists who adapted their hypotheses and goals to evidence had high rates of success in rediscovery.		known) of important components in their endeavors instead of searching for new ideas or opportunities. - Recognition of entrepreneurial opportunity seemed 'instinctive' to the eight entrepreneurs, respectively.

As predicted by the hypothesis and supported by the zeitgeist, three out of the four sources indicated a correlational relationship between the type of scientific process an individual employs and the innovation they produce. Source A highlighted how scientists' use reasoning to determine/predict the value of a certain scientific endeavor. Source B demonstrated that a greater flexibility in scientific methodology correlates with an increased likelihood of progress and breakthrough. In source D, the interviews with eight successful entrepreneurs revealed a common utilization of recognition methods in their endeavors, suggesting a connection between their success and the specific type of mental processes they employed.

Figure 3 – Environmental/External Exposure: Effect of Colleagues and Teams in Scientific Settings on Discovery

Source A: *"Exploring Uncharted Territory: Knowledge Search Processes in the Origination of Outlier Innovation"*	Source B: *"How Scientists Really Reason: Scientific Reasoning in Real-World Laboratories"*	Source C: "The Paper Trail of Knowledge Spillovers: Evidence from Patent Interferences"	Source D: *"Prior Knowledge and the Discovery of Entrepreneurial Opportunities"*
- Scientific reasoning (deduction & induction) used by scientists to predict, identify, and follow through with a valuable endeavor: finding	- Vitro: - Scientists following ridgid methods of		- All eight entrepreneurs→utilized recognition (closely related to what the

where a solution/answer could be found and distant recombination. - Prediction of nanotubes conductivity catalyzing a new generation of chip technology. - Patent for using water stabilized antimicrobial organosilanes: followed an unusual approach of fundamental chemistry. - Interviews with separate innovators Jason Gestwicki and James Murto revealed: different approaches in their inventions/methods than colleagues.	rediscovery and pursuing unaltered hypotheses/goals did not succeed in fulfilling their task of discovery. - Scientists who adapted their hypotheses and goals to evidence had high rates of success in rediscovery.		individuals had already known) of important components in their endeavors instead of searching for new ideas or opportunities. - Recognition of entrepreneurial opportunity seemed 'instinctive' to the eight entrepreneurs, respectively.

As expected by the hypothesis and the zeitgeist, three out of the four sources indicate a correlation between a scientist's social setting and colleagues with their processes and generation of innovation. In source A, the combination of two professionals' specialized knowledge led to the creation of a new product, highlighting how colleagues working together can play a big role in discovery. In the second source, the way scientific ideas were communicated, which is important in progressing projects or research and in shaping a scientist's conceptual standing, relied heavily on the input of colleagues. In source D, the entrepreneurial businesses had used networking and interdisciplinary collaborations–similar to source A–to produce their respective unique applications of MIT's 3D printing technology.

Discussion and Conclusion

Results indicated that the different facets of environmental exposure, such as the scientific processes leading up to the innovation (Figure 2), social settings or colleagues (Figure 3), and pre-exposed knowledge (Figure 1), do all seem to affect discovery and innovation. Because the hypothesis relies on the establishment of the zeitgeist's significance in innovations, the repeated influence of environmental exposure on discovery and invention seen in all three figures supports the hypothesis. This data aligns with secondary research. One alignment can be seen in how certain types of scientific processes employed–such as in the form of procedural limitations or approaches within a scientific investigation–may result in parallel products or ideas when duplicated and employed by different parties within the same disciplinary context (Stokes, 1986). As for the influence of social surroundings on innovation, the data presented in Figure 3 is corroborated with Gladwell's (2008) article about the importance of interdisciplinary collaboration in producing successful patentable innovations. Lastly, the data about pre-exposed or background knowledge presented in Figure 1 is consistent with Dr. Idhe's (1948) proposal that different aspects of pre-exposed knowledge such as the accumulation of knowledge in a specific

discipline are tied to the production of discoveries and inventions within that discipline. Because the data collection demonstrated that the zeitgeist was almost always prevalent in innovation, whenever there is a change in environmental influences, there are more possibilities for new inventions or discoveries born out of those new environmental surroundings. This means that the inevitable occurrence of change in environmental factors (both in the scientific and socio-cultural realms) leads to more new inventions and discoveries being created, stemming from that new information or influential factors that scientists are exposed to. This close tie between the zeitgeist and the production of innovations predicts that, when environmental exposures are shared between two or more parties, innovations must also have higher chances of being shared or duplicately produced. The high frequency of SIs–as seen in literature– and their tie to the zeitgeist, affirms this prediction and affirms both the ideas that SIs are manifestations of scientific advancement's inevitability, and–in turn–that SIs are sufficient methods for examining such inevitability.

Although the data collected offers important information about the relationship between a scientist's surroundings and their innovations, limitations of the systematic review may have impacted the quality or validity of its concluding results. The most evident limitation of the data is the small number of studies (four) being assessed in addition to the bias that may have influenced their selection. Disadvantages within the individual sources include how source C had minimal information in Figures 2 and 3, which further lowers the diversity of information within those figures, while source D–although offers insight into the process and generation of innovation–mainly focuses on the innovations of entrepreneurs who are not all fully versed and who do not all directly deal with science or scientific data. A larger and more diverse data set is needed to fully and accurately capture the impact that different forms of environmental factors have on discoveries and inventions. An improved data set should also include observational and simulated studies–similar to the ones documented in source B–because they are needed to capture the full extent of influence that environmental exposures have on different facets of discovery and invention. Incorporating such raw data is important as it allows the different environmental exposures to be mapped out in detail and studied in depth.

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Splitting Isolated Electrons and Proposition of a New Model of an Electron By Anirudh Kulkarni

Abstract

This paper presents a potentially groundbreaking discovery in the field of particle physics. It details a method for splitting isolated electrons using electromagnetic radiation. The experimental approach and observed outcomes could open new doors for understanding particle interactions and have far-reaching implications for various scientific and technological domains. The results also sketch a possible new model of the electron, suggesting the existence of a new particle within it. This model attempts to explain some of the major properties of electrons, particularly excitation and changes in energy levels.

Keywords: Splitting Electrons; Discovery of a New Particle; New Model of an Electron

Introduction

Particle physics has long sought to uncover the fundamental nature of subatomic particles and their interactions. This study proposes a novel method to split isolated electrons using electromagnetic radiation and the inter-repulsive forces between electrons. The observed results, which appear to contradict the standard model due to the anomalous behavior of the electrons, lead to the proposition of a new model that better explains the observed behavior and potentially explains excitation and changes in energy levels. The motivation behind this research is to explore alternative pathways for manipulating particles and potentially harnessing the outcomes for practical applications.

Methodology

The experiment performed utilizes principles related to nuclear fission and the photoelectric effect. The idea of colliding particles is valuable because the released energy can provide insights. The photoelectric effect isolates the electrons for experimentation.

Materials

The materials used to perform this experiment are as follows:

1) A small airtight chamber (3 × 1 × 1 inch).
2) Two power sources.
3) Two electromagnets, each with 200 windings of copper wire.
4) A blue LED bulb.
5) Aluminum foil (chosen because it does not exhibit significant magnetic properties).

Procedure

We first place the two electromagnets on opposite sides of the small chamber, ensuring their like poles are parallel. Then, using a string, we tie a small piece of crumpled aluminum foil

in the center of the apparatus between the solenoids. To make changes in the foil more visible, we first crease it by crushing and reshaping it. Next, we position the blue LED bulb, powered separately, over the aluminum to isolate the electrons present in it.

Results

The foil curls prominently at the point where the light rays strike more intensely. This is likely due to the electrons being ejected from their orbitals. After 75 seconds, the battery powering the electromagnets overheats by 3 degrees Celsius. However, the electrons cannot pass through the circuit or the battery because the electromagnets push them towards a single concentrated point. The reason for the battery overheating is unclear, but the internal resistance of the battery could be a factor. Notably, the constant rise in temperature stops immediately when the separately powered bulb is turned off. This makes it difficult to pinpoint any experimental errors definitively.

One possible explanation is that the ejected electrons collide at a single point in the center of the apparatus due to the electromagnets pushing them together. Once concentrated, these electrons encounter electromagnetic radiation on either side. The repulsive forces between the electrons and the collisions with the electromagnetic radiation cause a significant disruption to the electrons' particle-wave nature, potentially leading to splitting. This behavior is explained using a water analogy inspired by the pilot wave theory, which the author has named "Anirudh's Quantum Phenomenon."

Imagine a still plate of water. This still water represents the particle-wave equilibrium of an electron (or any other particle exhibiting wave-particle duality). When we tap the edge of the plate, a wave is produced. This wave mimics the behavior of any other particle or radiation that disrupts the equilibrium of the electron's particle-wave duality. Here, the electron struggles to reach equilibrium when exposed to this disturbance wave. When the tapping becomes more intense, some of the water spills out. These spilled droplets are very tiny compared to the plate of water and are also still, representing equilibrium. These droplets represent the inside of an electron, which the author proposes is a collection of tiny negative charges named "Brahman particles."

The existence of the Brahman particle can be investigated using the conservation of energy for electric fields and particles. The equation $\int S \bullet dA = -(dE/dt) – W$ can be helpful in determining the existence of the Brahman particle. The value of (dE/dt) is constant at -2.62×10^{-24} Joule. With the total energy, we can calculate the charge of the Brahman particles released, which is approximately -1.87 × 10^-56 eV to -1.9×10^{-56} eV. This value represents the charge of the collective Brahman particles present. The charge of a single Brahman particle would be **-2.2×10^{-90} eV**, which is very small, almost billions or trillions of times smaller than the energy associated with a **single electron**. The value of (dE/dt) should not be that small since the electric and magnetic fields acting on the electrons are strong compared with the size of the apparatus.

$\int S.dA = -\frac{dE}{dt}$ -W

Since the Electric field and Magnetic field is uniform only on the surface of the Aluminum foil, the revised equation we get is:

$S \times A = -\Delta E - W$

$S = E \times B$

$E = \frac{Kq}{r^2} = -2.23 \times 10^{-6}$

$B = \frac{\mu I}{2\pi r} = 4.72 \times 10^{-6}$

$S = -10.52 \times 10^{-12}$

$S \times A = -80.15 \times 10^{-14}$

$\Delta E = \frac{1}{2} \times \epsilon \times E^2 \times V = 1.64 \times 10^{-24}$

$\therefore W = 81.79 \times 10^{-28} Joule$

$q = E \times r^2 \times 4\pi\epsilon = -1.87 \times 10^{-56} eV$

$q = n \times e \rightarrow n = \frac{q}{e} = 8.4 \times 10^{35}$

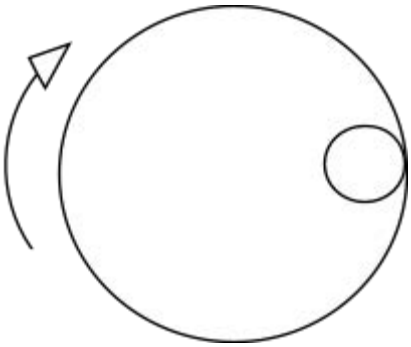
The number of Brahman released in this experiment is 8.4×10^{35}; the collective charges released is $-1.87 \times 10^{-56} eV$, from these values we can calculate the actual charge of the Brahman and the number of Brahman present in one electron.

$Q = \frac{-1.87 \times 10^{-56}}{8.4 \times 10^{35}} = -2.2 \times 10^{-90} eV$

$n = \frac{1.6 \times 10^{-19}}{2.2 \times 10^{90}} = 7.2 \times 10^{70}$

Considering the size of the apparatus, the resultant value should be larger. This means that there are some energy absorptions taking place, which proves the possibility of another particle, that is the inside of an electron; it is possible that the brahman is responsible for the excitation of an electron and the change in the energy state of an electron, which is explained below.

New Model of an Electron:



Electrons are traditionally imagined as spheres. This new model proposes another sphere existing inside the electron. This inner sphere is a collection of billions, trillions, or $\mathbf{7.2 \times 10^{70}}$ tiny negatively charged particles named "Brahman particles." These Brahman particles come together in the presence of a nucleus because the attractive force of the nucleus is greater than the repulsive forces between these particles. This force causes them to form a sphere that tends to move near the nucleus. Since the electron and the Brahman sphere are in equilibrium, the Brahman sphere revolves along the inside of the electron, which in turn causes the electron to revolve around the nucleus. The revolution occurs due to the inertial forces acting on the electron and the attractive force between the Brahman particles and the nucleus of an atom. According to this model, the given quantum phenomenon can also explain the wave nature of an electron.

Conclusion

This paper proposes the possibility of splitting electrons using specific materials. It also presents a new model of the electron to explain the phenomena observed in the experiment and suggests a possible cause for electron excitation. The existence of the new Brahman particle is also proposed in this paper. While there are limitations to this research, the concept of splitting electrons explained here could be valuable for further exploration in this field.

Comparative Analysis of the Efficacy of Zinc Oxide and Titanium Dioxide as Heat-Reflective Additives in Paint by Nayoung Kim

Abstract

This research assesses the effects of zinc oxide (ZnO) and titanium dioxide (TiO_2) additives on the heat-reflective properties of standard white paint and their potential to improve building energy efficiency. Controlled experiments were conducted to measure the impact of adding ZnO and TiO_2 to paint, both individually and in combination, on the surface temperatures of painted cardboard samples. There was a notable decrease in temperature with the introduction of ZnO. The samples with 5 and 10g of ZnO had average maximum temperatures of 36.5°C and 36.3°C, respectively, while the control paint had an average maximum temperature of 36.8°C. The addition of TiO_2, in contrast, was found to have a negligible impact on cooling, with temperatures for 5g and 10g additions registering at an average maximum of 36.7°C, similar to the control. Combinations of 5g of ZnO and 5g of TiO_2, as well as 10g of each, resulted in average maximum temperatures of 36.4°C and 36.3°C, respectively, suggesting that there was no significant synergistic effect between the ZnO and the TiO_2. The findings elucidate the complex interactions of these oxides in paint formulations and indicate that while ZnO can effectively enhance the heat reflectivity of paint. The role of TiO_2 and its interaction with ZnO warrants further investigation. The study's insights are pivotal for developing and optimizing paints for energy conservation, highlighting the promise of ZnO for use in mitigating urban heat islands and contributing to the sustainability of urban dwellings.

Introduction

The quest for energy efficiency in buildings is a pivotal challenge in modern urban development, reflecting a broader commitment to environmental sustainability and economic viability. In this context, thermal insulation paint technology emerges as a promising solution, offering a novel approach to reducing the energy costs associated with heating and cooling buildings. By enhancing the thermal regulation of building exteriors, these innovative coatings, known as thermal insulation paints, play a crucial role in minimizing heat exchange. This ensures interior temperatures are comfortable across seasons and significantly contributes to energy conservation efforts (Lü et al., 2019).

Central to the effectiveness of thermal insulation paints are (Yue, 2019). These compounds are celebrated for their ability to reflect ultraviolet and infrared rays, thereby reducing the absorption of solar heat. Yet, the true potential of these paints hinges on a complex array of factors: the chemical makeup of the paint, the specific properties of the additives, the surface characteristics of the application area, and prevailing environmental conditions. This multifaceted interplay necessitates a deep exploration to optimize paint formulations for maximal thermal insulation.

Emerging research underscores the critical role of nanoparticle size and distribution within these formulations. The unique properties of nanoparticles, notably their increased surface area, may significantly amplify the reflection of solar radiation, thereby enhancing the insulation capabilities of the paint. This insight directs our attention toward the nanostructural optimization of ZnO and TiO_2 as a pathway to bolster the energy efficiency of thermal insulation paints.

The implications of advancing thermal insulation paint technology are profound. As cities grow and the demand for sustainable building materials escalates, the development of reflective paints optimized with ZnO and TiO_2 stands at the forefront of innovation. Such materials can lead to direct energy savings and be used to help address the urban heat island effect—the phenomenon whereby urban regions have elevated temperatures compared to their rural counterparts due to human activity. This effect underscores the urgency to adopt energy-efficient solutions in building materials. However, the journey toward integrating these advanced paints into the mainstream construction industry involves addressing several practical challenges (Zhang et al., 2015), such as the durability of the coatings, their long-term resistance to environmental degradation, and the consistency of their thermal regulation properties. Additionally, the environmental friendliness of ZnO and TiO_2, marked by their non-toxicity and minimal ecological impact, enhances their suitability for use in sustainable construction practices.

This study aims to dissect the influence of varying concentrations of ZnO and TiO_2 on the heat-reflective properties of paint. Through a series of thorough experiments, we endeavored to refine the formulation of thermal insulation paints, thereby contributing to the next generation of sustainable construction materials. By elucidating the optimal conditions under which these additives exert their maximal reflective capabilities, we sought to advance the field of energy-saving solutions for the built environment, paving the way to a future in which buildings shelter people and actively contribute to energy conservation.

Materials and Methods

Materials

We started by selecting a standard white acrylic latex paint renowned for its wide usage across commercial and residential settings to ensure our findings would have broad applicability (Solano et al., 2020). This base paint, which is favored for its user-friendly application, rapid drying capacity, and matte finish, served as an ideal medium for evaluating the reflective attributes central to this study. In our investigative focus, we focused on two pivotal additives, zinc oxide (ZnO) and titanium dioxide (TiO_2), which we selected for their unique protective and reflective qualities. ZnO, which is celebrated for its exceptional UV-blocking capability and protection against sun damage, was utilized in a non-nano form with particle sizes within the 200–500 nm range to optimize its reflective efficacy. We used TiO_2, which was chosen for its high refractive index and UV resistance, with particle sizes between 100–300 nm to enhance the scattering of solar radiation, thus maximizing reflectivity.

Fig 1 and Fig 2.
Left: ZnO powder, in a transparent packaging with a green label
Right: TiO_2 powder in a transparent packaging with yellow label

The experimental design involved the careful integration of these additives into the base paint to formulate distinct groups for analysis. This included single-additive groups with 5% and 10% ZnO and TiO_2 and a combination group in which both additives were mixed equally, culminating in a total additive volume of 10%. We ensured the additives were thoroughly mixed into the base paint by using a mechanical agitator until the mixture was homogenous.

Fig 3, Fig 4, and Fig 5.
Left: Digital scale initialized and tared to zero grams
Center: Incremental addition of powder, displaying a measurement of 10 grams
Right: Completion of powder addition, with the scale reading 20 grams

Fig 6, Fig 7, and Fig 8.
Left: Sealed can of standard paint, ready for use
Center: Clear mixing cup with 100ml mark
Right: Paint mixed with additives in a roller tray, demonstrating the final preparation step before application to cardboards

Sample	Paint Formulation
0	Untreated Cardboard Control
1	Baseline White Paint (100ml)
2	Baseline White Paint (100ml) + zinc Oxide (5g)
3	Baseline White Paint (100ml) + zinc oxide (10g)
4	Baseline White Paint (100ml) + titanium dioxide (5g)
5	Baseline White Paint (100ml) + titanium dioxide (10g)
6	Baseline White Paint (100ml) + zinc oxide (5g) + titanium dioxide (5g)
7	Baseline White Paint (100ml) + zinc oxide (10g) + titanium dioxide (10g)

Figure 9. Visual comparison of cardboard samples treated with different paint formulations, labeled 1 through 7 corresponding to the samples detailed in the table.

Methodology for Testing Heat Reflectivity

When evaluating the heat reflectivity of various paint formulations, we took cues from established research in which surface temperature metrics were found to be linked to reflective properties. Inspired by Kinoshita and Yoshida (2016), we focused on temperature differentials as

a reflection of the paint's capability to reflect solar energy. The insights of Kinoshita and Yoshida (2016) concerning the impacts of pigment properties, such as particle size, helped us refine our approach to measuring reflectivity via thermal response.

The work of Miszczyk and Darowicki (2003) informed our understanding of how temperature influences the protective attributes of paint coatings. Their findings about the mechanical and protective properties of coatings under temperature variations were essential to our evaluations of the durability of our samples. Synnefa, Santamouris, and Livada (2006) provided a comparative analysis of reflective coatings, and their results were instrumental in developing our hypothesis. Their evidence suggested that coatings yielding cooler surface temperatures under controlled conditions were more reflective than others—a principle we tested in our own experimental setup. Rupesh et al. (2018) introduced temperature-indicating paints (TIPs) as a method for measuring temperature distribution. Although we did not directly apply TIPs, the principles behind their use reinforced the validity of the use of indirect temperature measurement in assessing the heat reflectivity of our paint samples. The use of these diverse research approaches enabled us to design a rigorous experimental procedure. This protocol was used to meticulously record the thermal reactions of painted surfaces exposed to infrared radiation so we could indirectly measure their heat reflectivity.

The height at which the 150W infrared light bulb was positioned above the sample surface was carefully standardized at 22 cm. This precise distance was maintained to ensure consistency in the irradiance received by each sample. We used a FLIR ONE thermal camera to capture the thermal profiles of the samples during infrared radiation exposure, providing a detailed temperature map that was instrumental in assessing the reflective characteristics of the coatings. This controlled setup enabled us to perform an accurate comparative analysis of the paint's ability to reflect infrared radiation—a key factor in the energy efficiency of building materials.

Figure 10 and Figure 11.

Left: FLIR ONE thermal camera used to capture the thermal profiles of the paint samples
Right: 150W infrared light bulb to simulate sunlight

Our experimental procedures were rigorously standardized to ensure we produced reliable and reproducible results. All trials were conducted in a temperature-controlled laboratory environment in which the ambient conditions were carefully maintained at 23°C with a relative humidity of 40%. These stable conditions were continuously monitored to mitigate any potential environmental influences on our outcomes. Regarding sample orientation, we placed each cardboard box in a horizontal position with the painted surface facing upward. The infrared light source, which was set to a consistent height, was precisely aligned to be perpendicular to the samples, thereby minimizing any impact of radiation source angle on our temperature readings.

Figure 12 and Figure 13.
Left: The infrared light source set up above the sample area without the sample present
Right: Introduction of the untreated cardboard sample under the infrared light

Calibrating our instruments was very critical. Before we started each test, we calibrated the FLIR ONE thermal camera, which was a step-by-step process, using a black-body radiator. This black-body radiator was purposely set at a very known temperature, because we only specialized on the area that had the highest temperature, and then we calibrated the highest temperature of all the different surfaces of the cardboard. We also conducted some time-series analysis. We did this to determine whether the data would even out over time. The experiment was run for 20 seconds at a time for 3 minutes. Then we repeated everything five times to enhance the reliability of our findings.

Results

Presentation of Temperature Data for Each Paint Formulation

Sample	Paint Formulation	Maximum Temperature (°C) among 5 trials	Average Maximum Temperature (°C)
0	Untreated Cardboard Control	40.5	40.3
1	Baseline White Paint (100ml)	37.0	36.8
2	Baseline White Paint (100ml) + zinc oxide (5g)	36.7	36.5
3	Baseline White Paint (100ml) + zinc oxide (10g)	36.4	36.3
4	Baseline White Paint (100ml) + titanium dioxide (5g)	36.8	36.7
5	Baseline White Paint (100ml) + titanium dioxide (10g)	36.8	36.7
6	Baseline White Paint (100ml) + zinc oxide (5g) + titanium dioxide (5g)	36.7	36.4
7	Baseline White Paint (100ml) + zinc oxide	36.5	36.3

	(10g) + titanium dioxide (10g)		

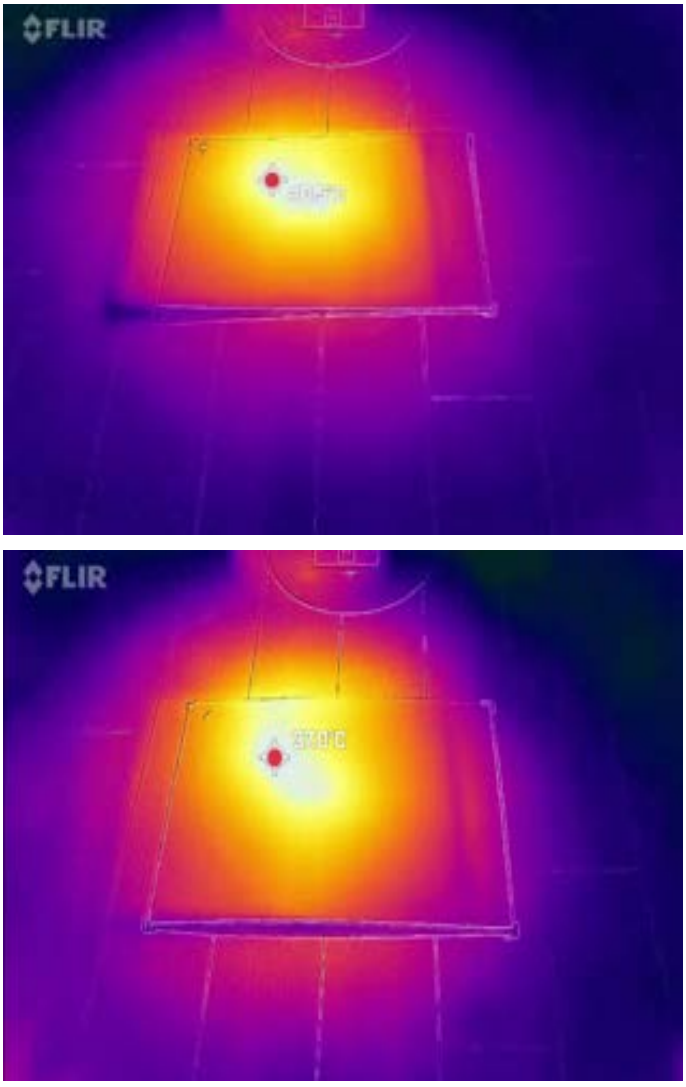


Figure 14 and Figure 15.
Left: Thermal image of cardboard sample 0 showing the maximum surface temperature of 40.5°C
Right: Thermal image of cardboard sample 1 showing the maximum surface temperature of 37.0°C

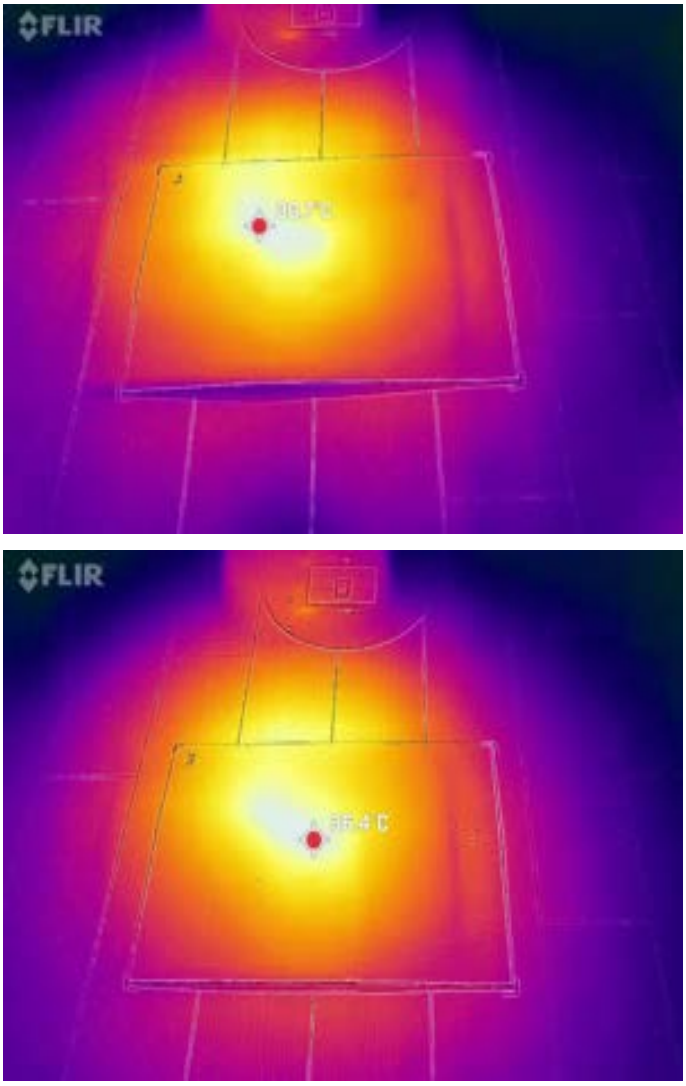


Figure 16 and Figure 17.
Left: Thermal image of cardboard sample 2 showing the maximum surface temperature of 36.7°C
Right: Thermal image of cardboard sample 3 showing the maximum surface temperature of 36.4°C

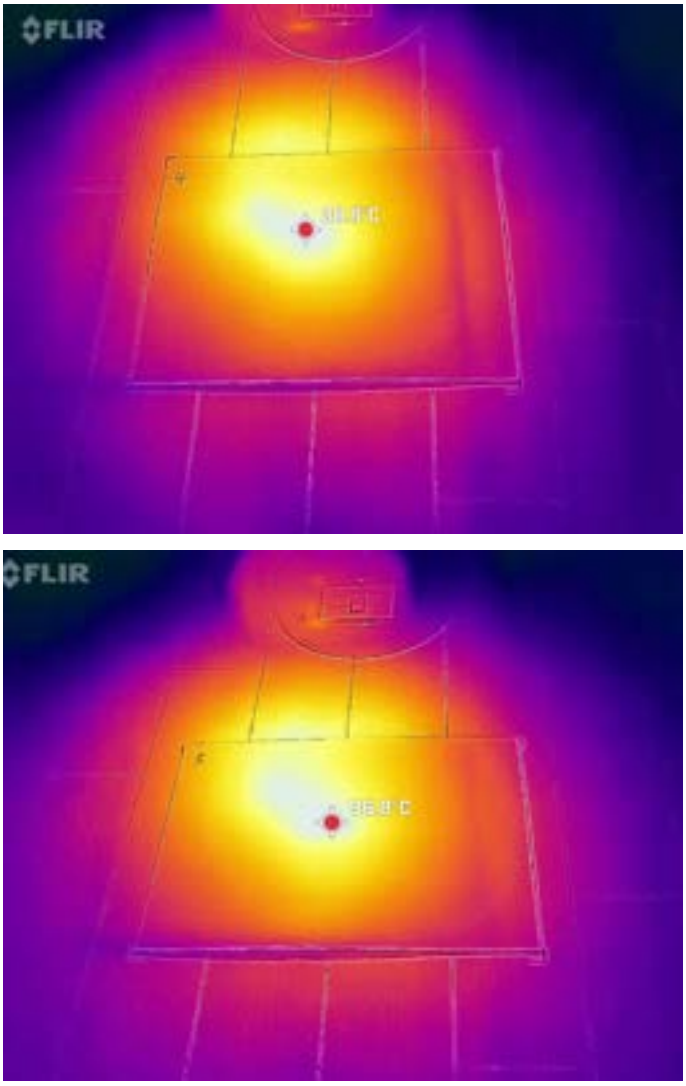


Figure 18 and Figure 19.
Left: Thermal image of cardboard sample 4 showing the maximum surface temperature of 36.8°C
Right: Thermal image of cardboard sample 5 showing the maximum surface temperature of 36.8°C

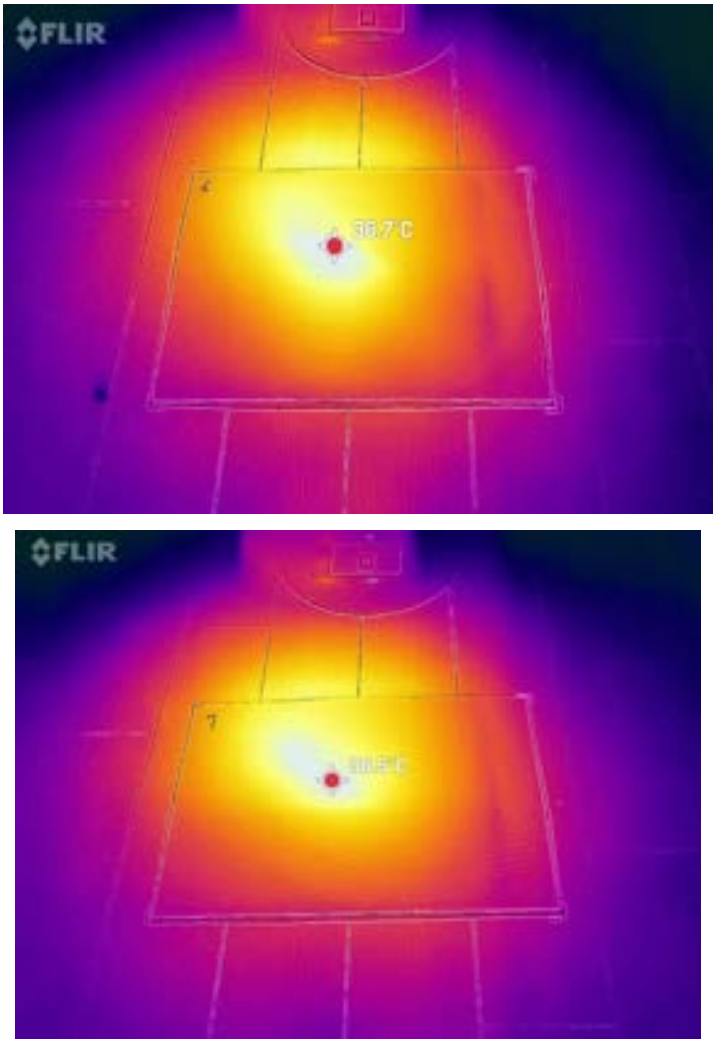


Figure 20 and Figure 21.
Left: Thermal image of cardboard sample 6 showing the maximum surface temperature of 36.7°C
Right: Thermal image of cardboard sample 7 showing the maximum surface temperature of 36.5°C

Results and Discussion

Analysis of Heat Reflectivity Based on Temperature Measurements

In the analysis of the thermal data about our paint formulations, the untreated cardboard control exhibited an average peak temperature of 40.3°C, establishing it as a baseline for thermal reflectivity assessment. This figure aligns well with the expected thermal absorption properties of dry, uncoated cardboard. Conversely, the baseline white paint showed a significant temperature reduction, with an average peak temperature of 36.8°C. The predominance of white

in this paint is a critical factor in its cooling effect. This aligns with the findings of Wang, Huang, and Li (2020), who underscored the efficacy of white surfaces in lowering temperatures due to their high sunlight reflectivity. Although they focused on geographical variations in the cooling effects of white roofs, their results provided us with a valuable reference for understanding the temperature dynamics observed in our paint samples. Additionally, the moisture content present in the wet paint likely contributed to the cooling effect through evaporative processes. In light of this, our results highlight the importance of color reflectivity and moisture in thermoregulation. These factors are essential considerations in the development and selection of paint formulations intended to promote energy efficiency and passive cooling in building design.

Impact of Zinc Oxide

Incorporating zinc oxide (ZnO) into paint formulations markedly impacts their capacity to reflect heat due to ZnO's inherent UV-blocking properties. Our results, which are consistent with those of prior studies, confirm that ZnO significantly improves the UV absorption efficacy of paint coatings, enhancing their heat-reflective characteristics. Our analysis of ZnO-infused paints revealed that it reduced the surface temperatures of the samples, demonstrating a dose-responsive behavior. The addition of 5g of ZnO to the baseline white paint resulted in an average maximum temperature of 36.5°C, a slight reduction from the baseline of 36.8°C. This trend continued with the addition of 10g of ZnO to the base paint, which further decreased the temperature to 36.3°C, substantiating the reflective benefits of ZnO.

These findings echo those of Girigoswami et al. (2015), who documented the effectiveness of polymer-coated ZnO nanoparticles in blocking UV radiation. Their findings elucidate ZnO's role in enhancing the UV protection of coatings, directly influencing their ability to reflect heat. Ahmad et al. (2021) also provided insights into the influence of zinc on the thermal and optical properties of materials, albeit in the context of solar absorption. Their results suggest that zinc, in different forms, can modify a coating's response to thermal energy.

One practical outcome of these findings is that ZnO will play a significant role in energy-efficient building design. Paints enhanced with ZnO nanoparticles can help reduce the cooling requirements of buildings, promoting sustainability and mitigating urban heat islands. Their application is particularly effective in light-colored paints for which ZnO's reflective action complements the base paint's inherent properties, yielding a composite material with superior heat-reflective capabilities.

Impact of Titanium Dioxide

The impact of titanium dioxide (TiO_2) on the heat-reflective properties of paint formulations has garnered significant attention due to its high refractive index and UV-blocking capabilities. TiO_2 plays a pivotal role in the realm of heat-reflective coatings by contributing to the reduction of surface temperatures, thereby enhancing the energy efficiency of buildings. This investigation sought to evaluate the potential of TiO_2 for use in lowering surface temperatures when incorporated into paint formulations. Upon integrating 5g of TiO_2 into a baseline white

paint, we observed a marginal decrease in the average maximum temperature from the baseline's 36.8°C to 36.7°C. This slight improvement in heat reflectivity underscores TiO_2's effectiveness in scattering UV light, which in turn, contributes to cooling. However, doubling the TiO_2 concentration to 10g did not yield a further reduction in temperature, indicating that the benefits of TiO_2 plateau beyond a certain concentration.

This observation challenges the conventional wisdom that high concentrations of TiO_2 invariably lead to high heat reflectivity. The initial temperature reduction achieved with a modest amount of TiO_2 can be attributed to its UV reflection capabilities. Nonetheless, the absence of additional temperature reductions at higher concentrations of TiO_2 suggests that there is an optimal TiO_2 concentration for maximizing reflectivity. Dalapati et al. (2016) studied transparent heat-reflecting coatings and demonstrated the utility of TiO_2 in energy-saving applications, highlighting its role in enhancing visible transmittance and IR reflectance after thermal treatment. Similarly, Liang et al. (2016) studied the light reflectivity of TiO_2 particles and emphasized the material's ability to increase reflectivity, which is crucial for the development of high-performing heat-reflective paints.

These findings necessitate a nuanced understanding of TiO_2's role in heat-reflective coatings. It appears that the efficacy of TiO_2 is not merely a function of its presence and is influenced by its interaction with the base paint and other components of the formulation. This insight is vital for the development of reflective coatings intended to maximize energy efficiency without incurring unnecessary costs or compromising other functional properties of the paint. In the future, researchers should focus on elucidating the mechanisms through which TiO_2 contributes to heat reflectivity and how it interacts with various paint formulations under different environmental conditions. Such information could pave the way for the creation of advanced paint heat-reflective formulations while ensuring cost-effectiveness and environmental sustainability.

Combination Effects of Zinc Oxide and Titanium Dioxide on Heat Reflectivity

The exploration of the synergistic effects of zinc oxide (ZnO) and titanium dioxide (TiO_2) paint additives in enhancing the heat-reflective properties of paint formulations was our focus in this study. Recognized individually for their UV radiation reflection capabilities, ZnO and TiO_2 contribute to thermal regulation when applied to coated surfaces. Our findings indicated that adding equal amounts of ZnO and $TiO_2$to white paint did not significantly enhance surface temperature reduction beyond the effects observed with ZnO alone. Specifically, paint samples containing 5g of ZnO and 5g of TiO_2 did not exhibit a marked improvement in temperature reduction compared to samples with 10g of ZnO. Similarly, doubling the combination to 10g each of ZnO and TiO_2 did not lead to a lower average surface temperature of the painted samples, challenging our initial hypothesis that there is a straightforward additive or synergistic effect between the two materials.

This outcome suggests that although ZnO and TiO_2 independently contribute to heat reflectivity, their combined application within a paint matrix does not necessarily result in enhanced heat reflection. This phenomenon may be attributed to the optical properties of the materials and their interactions within the paint matrix, where the scattering and absorption mechanisms critical to heat reflectivity could be optimized at certain concentrations, beyond which additional material does not enhance the effect. Amir et al. (2017) studied the synergistic effects of TiO_2 and zinc borate on the thermal stability and water resistance of intumescent fire retardant coatings, providing insight into the complex interactions between TiO_2 and other materials. Although they focused on fire resistance, their findings highlight the potential to improve the heat reflectivity of such coatings through the strategic combination of materials, which could extend to heat reflectivity in paint formulations (Amir et al., 2017).

Furthermore, Fu et al. (2015) studied $Ti3^+$ self-doped titanium–zinc hybrid oxides and found that the photoabsorption capabilities of these materials in the visible light range can be enhanced through self-doping, suggesting that they have indirect effects on temperature regulation through photocatalytic activity. This study's results underscore the importance of understanding the structural, morphological, and optical properties of material combinations for optimizing their application as coatings (Fu et al., 2015). These observations underscore the need for a strategic approach to combining reflective additives in paint formulations. Understanding the interactions between ZnO and TiO_2 could unlock new pathways to optimizing their combined efficacy in reflecting solar radiation. Further research into the particle size, dispersion, and optical interactions within paint formulations is warranted to provide deep insights into how to achieve enhanced heat reflectivity through material combinations.

Interpretation and Implications

Through our exploration of the effects of zinc oxide (ZnO) and titanium dioxide (TiO_2) on the heat reflectivity of paint formulations, we yielded insights into their individual and combined impacts. We found that ZnO effectively lowers surface temperatures, indicating that it has utility in heat-reflective paint applications. However, the addition of TiO_2 did not significantly enhance this cooling effect. Furthermore, the combination of ZnO and TiO_2 did not linearly improve heat reflectivity, suggesting that complex interactions affect their performance in paint formulations. These findings align with those of Driel et al. (2018), who investigated the degradation rates of TiO_2-based oil paints in various formulations, including those containing ZnO and TiO_2. They underscored the critical role of formulation on the optical properties of paints, such as light scattering and absorption, which are fundamental to understanding the reflective and protective capabilities of paints enhanced with ZnO and TiO_2 (Driel et al., 2018). This research is invaluable for discussions on optimizing paint formulations for energy-efficient applications, highlighting the significant roles that ZnO and TiO_2 can play in enhancing heat reflectivity. The broader implications of these insights are significant for the development of energy-efficient building materials. A deep understanding of the optimal balance and interactions between ZnO and TiO_2 can lead to coatings that more effectively reflect solar radiation, thus

reducing building cooling demands and contributing to sustainable urban development. The complex interactions observed, however, point to the necessity for further research to fully leverage the potential of these materials in reflective applications. Future research should delve into the mechanisms through which ZnO and TiO_2 interact within coatings, examining how variations in ratios, particle sizes, and combinations affect their reflectivity and UV protection properties. Such investigations will guide professionals in the development of advanced reflective paints, offering improved energy efficiency and aligning with global sustainability and energy conservation goals in construction and urban planning.

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Artificial Intelligence and Cancer by Mohini Chahal

Abstract

The phrase "Artificial Intelligence" is familiar or recognized by almost every individual working in any STEM field or with an online presence. Although Artificial Intelligence is nearly everywhere by now, the field is only going to continue growing. While AI is employed in many fields, including healthcare, finance, transportation, and social media, this paper will focus on the use of Artificial Intelligence in healthcare, specifically cancer. Cancer is a disease where cells in the body of the infected grow uncontrollably by cell division. These damaged cells can clump together to form tumors; which are either benign, meaning they are not harmful, or cancerous. Cancerous tumors will inevitably spread from one part of the body to another; this is the reason why it is imperative to detect cancer in its early stages. Artificial Intelligence is already used in different ways to help detect and treat cancer, but there are several other ways that it can be utilized. These include: early diagnosis, patient prognosis & assessing risk, and selecting the right treatment.

Introduction to Cancer and Artificial Intelligence

Cancer is one of the leading causes of death globally. "Approximately 39.5% of men and women will be diagnosed with cancer at some point during their lifetimes" (National Cancer Institute). This is merely 10% away from half of the entire population being faced with a cancer diagnosis during their life. Of all these patients, almost half are diagnosed at an advanced stage, which is an extremely high percentage, considering that cancer at advanced stages is significantly harder to treat. The process of staging is one where doctors assess how much cancer is in the cells of the affected patient, and whether the disease has spread to other parts of the body yet. The key is to catch the cancerous cells and stop them before they are able to affect other parts of the body, causing a tumor. Treatment decisions are then made based on which stage the cancer is currently at, and early-stage cancer diagnoses may see surgery as a potential option.

The idea of Artificial Intelligence being used to detect and treat cancer is not a new one. Several doctors and researchers have found that AI in the healthcare field is promising, and there has been work done on this previously. The National Cancer Institute has looked into how AI can be used to detect clusters of growing prostate cancer in MRI scans using a deep learning algorithm. Furthermore, their article explains how this can be used for less experienced radiologists, to help them "find prostate cancer when it's present and dismiss anything that may be mistaken for cancer." The article also goes into detail about cancer imaging, detection, error rates, treatment options, and more which will be explored later on in this paper. A different article from Targeted Oncology mentions "pattern recognition and natural language processing," which are two assets in machine learning that are used to analyze the medical records and history of a patient. There is a growing fear that Artificial Intelligence will take over the medical field and several other careers, which the article comments on by stating that "It is hard to imagine an area of medicine that AI and ML will not impact" (Kachaamy). However, it is important to

realize that AI would be used to simply enhance and improve efficiency, not take over doctor's jobs. The growth of this field has been so fast and rapid, that it is hard to imagine any field which it can not be used in. As seen by the articles mentioned previously and several others, AI already is and most definitely will continue to be used in cancer research.

It has been mentioned many times that AI will be used in cancer research, but now it is time to look at how it can be used. In order to understand this, there needs to be a brief introduction to the following: microscopic biopsy, MRI scans, pathology assessments, image analysis, supervised learning versus unsupervised learning, and datasets. Microscopic biopsy is vital in searching for the presence of cancer. It is when a small amount of tissue is removed from the body, and cells are looked at closely to determine whether they are cancerous or not. MRI stands for medical resonance imaging, and it is used in radiology to provide an image of the processes going on in the human body. MRIs work by using strong magnetic fields, magnetic field gradients, and radio waves. They can help doctors find cancer in a patient's body, as well as identify whether it has spread to other parts of the body yet or not. Pathology assessments are tests conducted on blood, urine, stool, and bodily tissues. These tests are interpreted by a pathologist and searched for numerous diseases, including cancer, as well as used to assess the reaction of a patient to certain medicines. Image analysis is when a computer analyzes an image to search for relevant information. This can be based on density, color, or size. Image analysis and scans done by doctors are closely related when it comes to looking for cancer, which will be explored shortly. Supervised and unsupervised learning are two different types of machine learning. The goal of supervised learning is to classify data, and predict outcomes of certain situations, while unsupervised learning sorts data. "Supervised learning uses labeled training data, and unsupervised learning does not" (Google Cloud). What does this mean? Labeled training data is marked as either an input or an output, and this data is used in supervised learning. Unsupervised learning analyzes and sorts datasets that are not labeled. Supervised learning is usually more accurate than unsupervised learning, and it is split into two types: classification and regression. Classification assigns test data into specific categories, and regression uses an algorithm to understand the relationship between dependent/independent variables. A dataset, used in machine learning, is a collection of data in different forms that is used to test models and algorithms along with training them.

The remainder of the paper will now use these terms and definitions to describe how exactly machine learning can be used to detect and predict the outcomes for cancer. This includes going over the idea in detail, along with its benefits, drawbacks, and logistics. Along with this, we will explore the next step in the merging of AI and healthcare, as well as look back at previous works which have experimented with this idea.

The Proposed Idea

It is time to put the pieces together and detail the entire idea behind using AI in the process of cancer treatment. The main area that machine learning would be used in is image interpretation, which takes radiologists a long time to study. There would be several things fed

into the dataset, including MRI scans, microscopic biopsy images, and the patient's medical history. The model would be trained with images of cancerous cells versus non-cancerous cells. Then, using supervised learning, the model would look at microscopic biopsy images and determine whether cancer is present or not. There are several pointers to look at in these cells which are red flags, and the model can be trained to look for these things specifically. Some of these flags include the size and shape of the cell, the size of the nuclei, and the distribution of cells in the tissue. If the tissue is cancerous, there would be a lesser number of healthy cells per unit area, and the nucleus in the cancerous cell is not found in the center. Once microscopic biopsy images are attained, the model can scan through the images and see whether anything looks suspicious. They can either mark the patient as affected, or unaffected: a classic example of classification in supervised learning. From here, doctors can go through the images which are marked as affected, and confirm whether or not the patient is affected. In order to train this model effectively, it would have to be shown thousands of images where there is cancer present, so that the model is able to identify and find cancer on its own. This process, once mastered, can be used for CT scans, MRI scans, and pathology tests as well.

The job of AI does not just end at cancer detection, however. It can also be used to choose a treatment. There are several imaging tests which are conducted to see how fast or far cancer has spread, and if they are fed into a ML model, then the model can once again look for red flags to see how much of a risk the patient is at. By looking at CT scans and MRI scans with clusters of cancerous cells, the model can be trained. It will first see several scans and images where patients are at high risk for cancer to spread, or where it has already spread. Then, it will be shown images where cancer is not likely to spread or did not spread. This will train the model about how to look for specific information that can be a telltale sign as to how high of a risk the patient is at. Then, images of a new patient will be used as an input, and the model will output how high of a risk the patient is at afterwards. Once again, using classification. Not only that, but after determining the risk, the model can offer advice on treatment. If the patient is at a very high risk and the cancer is likely to spread, then using its judgment, the model can suggest chemotherapy. If not, it can suggest radiation therapy, or medicine.

Benefits

There are several benefits of using Artificial Intelligence to assist humans in these ways . To begin with, radiologists and mostly all doctors work long hours every single day of the week. Looking at hundreds of images for a prolonged period of time all week can likely cause radiologists to make a mistake or miss something at some point. This chance of human error is eliminated once AI is used, because Artificial Intelligence is not subject to the mistakes humans can make even after being very experienced in a certain field. AI can look at thousands of images a day, and not get tired due to the fact that it has looked at that many. That is the beauty of it!

Additionally, radiologists will still inspect every scan/image on their own, but they can double check their diagnosis after checking it with what the Artificial Intelligence detected. If the radiologists somehow missed something, they are able to go back and look in greater detail to

ensure that they made the right decisions or correct their mistake. This process allows the model to continuously learn from its mistakes every time it detects something incorrectly. There is no guarantee that the program will not make the same error two times, but there is definitely a lower chance of it happening.

There are also plenty of benefits of using AI to determine which treatment option is best. There are several that could be added to the model to ensure they provide the best options. For example, the model could take into account the yearly income of the patient to see which treatment options would be the most cost-efficient, and based on the patient's request, they can factor cost into the decisions of what to choose. Not only that, but by giving the model lots of previous data, it can give the patient a realistic, candid percentage of success or chance of the cancer coming back. Radiologists have been looking at all kinds of treatments for their whole career, and this is an advantage for them. However, sometimes, they may develop a bias or misconception as to what option may be best. The AI model on the other hand, simply relies on facts and past data to offer treatment options. This allows the model and doctors to work together to think about what options are best for the patient, and who knows, after some more training, patients may be able to see the AI results firsthand as well.

Challenges

Of course, there will be some challenges that come along as AI gets more heavily involved with cancer detection. Firstly, the data being fed to the model would need to be 100% accurate and completely unbiased. If the model is trained using biased data, then it is prone to developing a bias of its own (Holdsworth). Additionally, there would need to be certain boundaries and lines to be drawn as to exactly how much doctors and AI should overlap. Doctors should not become overly reliant on AI models because as already discussed, the models can produce false positives and negatives.

Additionally, some AI models function as "black boxes", which means that they do not provide explanations behind why they have come to the conclusions that they did, and this could prove to be an issue. It will prove to be very helpful and important for AI models to explain why exactly they have chosen a type of treatment, or why they think that there is cancer in the images that they are provided in order for doctors to take their recommendations seriously. With all things considered, data privacy may become a serious concern to current and previous patients, which is why it would be necessary for patients to trust the models and provide their consent as to where their information is being given. These ethical and privacy concerns will need to be resolved before AI can be brought into the healthcare industry on a large scale.

Next Steps

The next steps to be taken in this process would be to start working on a model as outlined above, and to look for accurate and unbiased data that can be used to train the model. There will need to be steps taken in order to inform and educate patients on what AI is, and how it will be used in the future to give them a better treatment / diagnosis. Certain experiments can

be conducted, such as looking at the error rates of radiologists and oncologists in cancer detection, so that there is a focus on the weakest areas that AI can help out with.

Conclusion

Overall, using Artificial Intelligence in the healthcare field to diagnose and treat cancer patients would prove to be beneficial to both doctors and patients. A supervised learning model would be employed and it will be given data that is unbiased and accurate in order to provide the best results. The benefits as well as challenges of using this have been explored, and overall, if the model is well made, the benefits will outweigh the challenges.

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The Effects of Epigenetics on Transgenerational Trauma and Brain Anatomy By Ayma Fawad

Abstract

Transgenerational trauma is defined as the inheritance of psychological and physiological symptoms of trauma through multiple generations. For instance, when a parent has experienced a traumatic event, symptoms can manifest through biological mechanisms. Notably, studies have shown that epigenetics, defined as environmental influences on genetics, can affect DNA and cause transgenerational trauma. Research shows that the offspring of parents with trauma exposure are more likely to develop biological changes, which can induce developmental arrest, cognitive impairments, and increased prevalence of mood disorders. These factors hinder the offspring's ability to perform well socially and impair their learning capabilities. Furthermore, transgenerational trauma can play a role in the child's development due to in utero exposure to stress hormones, therefore priming the offspring towards higher levels of susceptibility to stress and other social factors. This review aims to further elucidate the current state of research regarding the underpinnings and effects of transgenerational trauma, representing a complex combination of epigenetics and biological changes.

Introduction

Trauma is caused by the exposure to a deeply dangerous or disturbing event, resulting in ongoing infliction and burdens (Yehuda and Lehrner). Consequences of trauma can manifest in many different forms, including lack of social interaction, delayed PTSD phenotype in which people's reaction times to events or stimuli are delayed, and other negative effects to daily tasks (Steenwyk et al., Bonanno and Mancini). Trauma exposure is dangerously prevalent across diverse populations, with over 70% of people having been exposed to a traumatic event at some point in their lives (Benjet et al.), including over 90% of clients in public behavioral health ("How to Manage Trauma"). Hence, there is a strong likelihood of developing these repercussions.

Not all symptoms of trauma stem directly from experiencing a traumatic event. Researchers have recently observed evidence that trauma, encoded in one's DNA, can be passed down to offspring - a concept called transgenerational trauma (Krippner and Barrett 53-62). Offspring and descendants may face biological challenges due to in utero stress exposure, which can lead to neuroanatomical developmental arrest, abnormal amygdala size (affecting emotional regulation), and chemical modifications like methylation (a chemical process in which a methyl group is added to DNA or other molecules) (Sarigedik et al., Yehuda and Lehrner). In turn, these biological challenges lead to impairment in people's daily lives, including social and cognitive challenges (Yehuda and Lehrner). This review paper will investigate the biology behind and the far-reaching consequences of transgenerational trauma.

Transgenerational Trauma

Researchers have paid increased attention to the long-term effects of parental trauma exposure on offspring outcomes. Transgenerational trauma develops as future generations display trauma phenotypes due to the inheritance of genetic markers from the previous generations' exposure to trauma (Yehuda and Lehrner). Genetic modifications occur due to external stress stimuli, which modify the individual's genetic markers. These genetic markers can in fact remain active and they have the potential to be passed down to their offspring and multiple generations (Steenwyk et al.). There are multiple types of transgenerational trauma: individual, familial, cultural, and historical. Individual and familial transgenerational trauma occurs when the direct offspring of a parent with trauma experiences biological and behavioral challenges as a result of the modified gene expression (Sarigedik et al.). Cultural transgenerational trauma (with context to historical events) refers to the long-term traumatic effects of cultural oppression, wars, and other historic events. (Kirmayer et al., Yehuda and Lehrner).

Transgenerational trauma has been studied and measured in various ways in humans, including behavioral observations (Bonanno and Mancini), brain imaging, and biological testing (Sarigedik et al., Yehuda and Lehrner). In addition, animal models have further demonstrated the extent to which transgenerational trauma can be passed down through up to 4 generations and affect biological markers - including increased glucose dysregulation (Steenwyk et al.).

Epigenetics Types

Epigenetics studies how behaviors and environments affect gene function ("Epigenetics, Health, and Disease"). For instance, when an individual experiences a traumatic event, the event can influence a cascade response and modulate gene expression in response to the traumatic event. The effects of epigenetics utilize gene modification processes such as DNA methylation, histone modification, and RNA signaling to affect gene function in response to trauma (Yehuda and Lehrner). Research has indicated that specific regions of genes, such as the gene NR3C1 which encodes the glucocorticoid receptor gene of resilience, contribute to long-lasting changes in gene function through the process of epigenetics (Yehuda and Lehrner, "NR3C1", Kubota). The internal impacts that epigenetics may have on someone can be passed down through generations. Epigenetics plays into transgenerational trauma when the trauma is around environmental factors.

Central and Peripheral Biological Impacts

Transgenerational trauma creates biological alterations in the offspring including altered metabolism, impaired stress response, and hypervigilance ("Persistent Fear and Anxiety"). The amygdalae of children whose parents experienced trauma were generally smaller and differently lateralized than non-trauma-exposed children, influencing cognition and emotions (Sarigedik et al.). Specifically, they find it difficult to stay attentive and switch between tasks, and they display more feelings of anger, sadness, fear, etc. (Sarigedik et al.). Researchers also observed elevated cortisol levels, affecting memory and stress response ("Persistent Fear and Anxiety") as well as

glucose dysregulation, which can impact behavior, energy, mood, and attention (Steenwyk et al.). In addition, gene methylation and other chemical modifications may be present (Yehuda and Lehrner). When mothers experience stress or trauma during pregnancy, their babies are prematurely exposed to stress hormones like cortisol, harming the development process, because the placenta supports both pregnancy and the mother's stress response (Yehuda and Lehrner). Overall, the offspring can be immensely impacted biologically during cases of transgenerational trauma.

Conclusion

In conclusion, transgenerational trauma represents a complex interplay between epigenetics and biology, leading to the inheritance of trauma-related symptoms across up to four generations. The major biological changes observed in offspring of trauma-exposed parents underscore the lasting impact of trauma on future generations. This study highlights the importance of understanding the molecular underpinnings of transgenerational trauma. Additionally, the social and cognitive disadvantages experienced by offspring further emphasize the need for interventions to address these impairments. Some existing interventions for trauma include cognitive behavioral/processing therapy, exposure therapy, and medications like sertraline and paroxetine ("Persistent Fear and Anxiety", "PTSD Treatments"). By understanding the specific mechanisms and effects of transgenerational trauma, we can further and more accurately mitigate its impact in our society.

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Lysergic Acid Diethylamide Reclassification Introduces a Potential Treatment for Alcohol Use Disorder: A Systematic Review By Elizaveta Vanurina

Abstract

Lysergic acid diethalymide's classification under schedule I of the UN convention on psychotropic substances has imposed significant legal and regulatory barriers to psychedelic usage in the scientific field. Reclassifying the hallucinogen could enhance scientific enquiry in therapeutic development, potentially offering a promising alternative for individuals suffering from alcohol use disorder. LSD's interactions with serotonergic and dopaminergic systems suggest its potential in modulating mood and behaviour, underscoring the possible implications for alcoholism. The substance's ability to induce profound transformative experiences may help individuals evaluate their relationship with alcohol. Acknowledging potential risks such as "bad trips" and confusion-controlled settings have demonstrated safety and lower toxicity of LSD compared to other drugs. Historically, studies from the 1950s and 1960s suggested the acid's potential. Nonetheless, earlier research often lacked methodological rigour, indicating the need for well-designed modern trials. Advocates argue that clinical research on LSD must continue to validate its potential benefits. In this paper we argue that with proper regulatory adjustments LSD could emerge as a viable treatment for alcohol use disorder, bridging the gap between current treatment modalities and patient needs.

Keywords: Lysergic Acid Diethylamide, LSD, Neurotransmission, Serotonergic and dopaminergic systems, Alcoholism, Alcohol use disorder, Psychiatry

Introduction

Lysergic Acid Diethylamide, commonly known as LSD, is a semisynthetic substance derived from Claviceps purpurea, a rye fungus, which was first synthesised in 1938 by Albert Hofmann (Calleja-Conde et al.). As a "classic psychedelic," LSD is known for its ability to profoundly alter consciousness, causing vivid hallucinations and distorting time and reality perceptions (Fuentes et al.).

Qualities of a classic psychedelic might enable LSD's use in treatment of mental disorders. Initially introduced in 1953 as a possible treatment for alcoholism, the drug's therapeutic benefits have been reinforced in recent research (Dyck 315).

The shift in focus from LSD's recreational use to potential advantages in mental health treatment, specifically alcohol use disorder (AUD), highlights the urgency to explore therapy options, given the significant rise in alcohol dependence cases (NIAAA). The Project MATCH experiments suggest that the existing psychological treatments for alcoholism are not so effective. The data from the research signified a gap between the treatment modalities in use and the actual needs of individuals suffering from alcohol dependence (Cutler and Fishbain).

Through exploring the neurobiological basis of LSD by reviewing existing clinical studies this paper attempts to show that reclassifying the substance can create new possibilities

for scientific inquiry and therapeutic development, ultimately offering a promising alternative for individuals suffering from alcoholism. The legal and regulatory landscape surrounding lysergic acid diethylamide is significantly influenced by hallucinogen's classification under Schedule I of the UN Convention on Psychotropic Substances. The categorization states that LSD has "no accepted medical use" and possesses the "greatest potential for harm," as noted by Rucker (2902). Such a stringent classification has had profound implications in many countries, imposing considerable legal and regulatory barriers that have in turn made research or medical trials involving the psychedelic exceedingly challenging to conduct. The given situation is particularly paradoxical considering the growing body of evidence suggesting potential therapeutic applications for LSD. The restrictive legal framework thus not only limits scientific inquiry but also potentially hinders the development of novel treatments that could benefit patients suffering from addiction.

LSD should be reclassified from its current Schedule I status to facilitate its use in research, as a potential treatment for alcoholism.

Methods

Search Strategy

In this study we delve into the ways LSD interacts with human neurotransmitter systems, serotonin and dopamine receptors. We focused on LSD's potential in psychiatry, addressing alcohol dependency. To guarantee a comprehensive review, we carried out a thorough literature search across databases JSTOR, PubMed and Google Scholar. The approach allowed us to capture a miscellany of systematic and narrative reviews related to LSD's history and pharmacology in context of alcohol use disorder.

Each database search was tailored to its unique indexing system and search capabilities, using a combination of terms and subject headings relevant to our research objectives. Our search strategy evolved through iterative refinement based on initial findings to encompass the largest possible spectrum of relevant literature. Two search strings were combined using the Boolean command "AND". The first string included MeSH terms referring to LSD: LSD, LSD-25, LSD 25, Lysergic Acid Diethylamide, Lysergic Acid, Acid Diethylamide, Lysergic Diethylamide, Lysergic Acid, Lysergide, Lysergic Acid Diethylamide Tartrate. The second string included terms describing alcoholism: Alcoholism: Alcohol Dependence; Dependence, Alcohol; Alcohol Addiction; Addiction,Alcohol; Alcoholic Intoxication, Chronic; Chronic Alcoholic Intoxication; Intoxication, Chronic Alcoholic; Alcohol Abuse; Abuse, Alcohol; Ethanol Abuse; Abuse, Ethanol; Alcohol Use Disorder; Alcohol Use Disorders; Use Disorders, Alcohol.

Inclusion & exclusion criteria

Potentially relevant systematic and narrative reviews published since 2005 were assessed for eligibility. Prior to screening, records were filtered by the presence of above mentioned MeSH terms in title. Further, our inclusion criteria focused on full-text articles, which provided

empirical data on LSD's effects on neurotransmission and the implications for alcohol dependency.

We particularly excluded articles focusing on other psychedelic substances, such as psilocybin, MDMA, ayahuasca and additional classic hallucinogens. Observations, experiments, reports and commentaries were omitted from the review.

Data screening and extraction

The investigation was conducted by one reviewer using standardised tools to ensure the reliability and validity of included studies. Quality assessment for the systematic texts was performed with the National Institutes of Health Study Quality Assessment Tools for systematic reviews and meta-analyses. The Scale for the Assessment of Narrative Review Articles (SANRA) was employed to evaluate the narrative reviews. Collected data included in Tables 1 and 2 references relevant information regarding LSD's neurobiological mechanisms and effects, implications for alcohol use disorder and empirical evidence of LSD's potential in psychiatry. Studies were grouped by review style for the synthesis.

Results

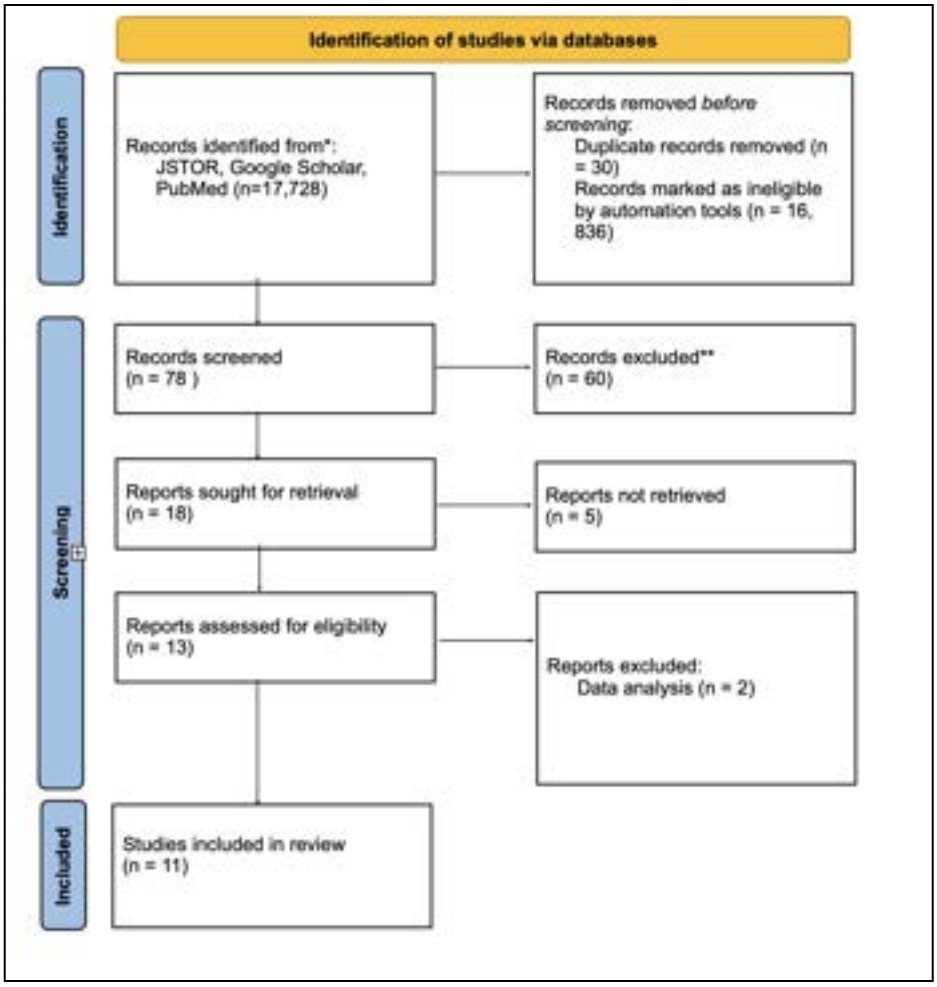

FIGURE 1. Flow diagram of identified, screened, included records and

Figure 1 depicts a flowchart of the selection process, produced using PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only. Eleven articles were incorporated in this review. From the originally noted 17,728 articles, 16,836 (94.9%) were excluded for reasons of duplicacy and irrelevance. Only 78 (8,7%) papers were screened from the 892 potentially eligible ones, as others did not meet the inclusion criteria regarding availability, article type and correspondence to the research objective. After abstract and title review, 60 (76.9%) studies were rejected. The remaining 18 articles were screened thoroughly, and 5 (27.8%) articles did not meet all of the inclusion criteria. The full texts of the 13 (72.2%) records were assessed, and 2 (15.4%) studies, which lacked comprehensive information on LSD and alcohol use disorder due to narrow focus on data, were excluded.

Out of the 11 articles present in the review, two types of reviews are evident: 7 (63.6%) were composed as narrative reviews, whereas 4 (36.4%) were systematic. The studies are of predominantly high quality, judging by the performed assessment. Tables 1 and 2 depict the relevant characteristics of the included reports, respectively. Papers were grouped by article type.

TABLE 1. Findings of narrative reviews exploring the relationship between LSD use and AUD.

Title	Author	Relevant findings
Hitting Highs at Rock Bottom': LSD Treatment for Alcoholism, 1950–1970	Dyck, Erika.	❖ H. Osmond coined the term "psychedelic" and believed that treating alcoholism biochemically would prove it was a disease rather than a moral failure. ❖ He conducted trials with over 700 patients resulting in life-changing experiences of many post-treatment. ❖ It is hypothesised that LSD might induce self-awareness and strength in individuals similar to effects of delirium treatments but without fatal risks. ❖ LSD often induced profound spiritual or transcendental experiences which led to lasting sobriety. ❖ The therapeutic benefits were linked not just to the chemical effects of LSD, but also to the profound personal insights and emotional experiences it induced.
Modern Clinical Research on LSD.	Liechti, Matthias E.	❖ Modern clinical studies on LSD have shown that the drug acutely induces a range of subjective effects, including emotional states, altering meaning of perceptions, derealization, depersonalization and mystical experience. ❖ LSD shows promise for reducing anxiety in patients with life-threatening diseases in clinical settings. ❖ Modern studies have highlighted the need for larger, controlled trials to validate these findings and further investigate the therapeutic

		potential of LSD in treating conditions such as anxiety, depression, and substance use disorder.
Psychedelics as Medicines for Substance Abuse Rehabilitation: Evaluating Treatments with LSD, Peyote, Ibogaine and Ayahuasca	Michael Winkelman	❖ Analyses of randomised controlled trials indicated significant short-term and medium-term reductions in alcohol abuse following a single dose of LSD. ❖ Effects tended to diminish by the 12 month follow-up. ❖ Psychedelics enhance serotonin addressing deficiencies found in addicts. ❖ Winkelman characterises the alteration of consciousness induced by psychedelics as "psychointegration", which involves the integration of emotional, sensory and cognitive processes.
Classic hallucinogens in the treatment of addictions	Michael P. Bogenschutz, Matthew W. Johnson	❖ A recent meta-analysis of six randomised controlled trials showed that 59% of participants treated with LSD had significantly improved outcomes compared to 38% in the control group. ❖ The 5-HT_{2A} serotonin receptor is linked to changes in perception and cognition. Classic hallucinogens may induce neuroplastic changes, such as dendritic remodelling which could underlie their long-term therapeutic effects. ❖ Further trials are needed to evaluate efficacy of LSD on alcohol addiction.
Psychiatry & psychedelic drugs. Past, present & future	James J.H. Rucker et al.	❖ Recreational use and associated societal issues led to psychedelics being placed in Schedule I under the 1967 UN Convention on Drugs. ❖ Initial interest in LSD came from its effects mimicking symptoms of psychosis.
Psychedelic drugs-a new era in psychiatry?	David Nutt, DM	❖ This article highlights the resurgence of clinical research on classical psychedelics such as psilocybin and LSD etc. This comes after decades of prohibition that halted promising research in the 1960s. Recent studies have shown highly promising results indicating the utility of these substances in treating various psychiatric conditions. ❖ The article details pharmacological mechanisms of psychedelics, focusing on their action as agonists at the serotonin 5-HT2A receptor, which is crucial for their psychedelic effects.

A Review of Lysergic Acid Diethylamide (LSD) in the Treatment of Addictions: Historical Perspectives and Future Prospects	Mitchell B. Liester	❖ LSD may restore dopaminergic homeostasis in the mesolimbic dopamine pathway, reducing the reinforcing properties of addictive substances. ❖ The effects of LSD are impacted by the environment in which it is administered.

TABLE 2. Findings of systematic reviews exploring the relationship between LSD use and AUD.

Title	Author	Relevant findings
Classic psychedelics and alcohol use disorders: A systematic review of human and animal studies.	Calleja‐Conde, Javier, et al.	❖ Lysergic Acid Diethylamide originates from Claviceps purpurea, a fungus found in rye. ❖ LSD was first synthesised in 1938 by Albert Hofmann.
Antidepressive, anxiolytic, and anti addictive effects of ayahuasca, psilocybin and lysergic acid diethylamide (LSD): a systematic review of clinical trials published in the last 25 years.	Dos Santos, Rafael G., et al.	❖ LSD's interaction with serotonin receptors in the brain, responsible for emotions, play a significant role in the substance's potential in treating AUD. ❖ A"Bad trip" can be characterised by extreme anxiety, dysphoria and confusion, leading to unpredictable behaviour when in an uncontrolled environment.
LSD helps to treat alcoholism	Frood, Arran.	❖ In 1953, LSD was identified as a promising treatment option for diagnosed alcoholics. ❖ The research landscape of the 1950s and 1960s on

		LSD-assisted psychotherapy demonstrates partial validity and relevance in contemporary scientific discussions.
Therapeutic Use of LSD in Psychiatry: A Systematic Review of Randomised-Controlled Clinical Trials	Fuentes, Juan J., et al.	❖ Fuentes conducted a retrospective analysis of LSD research, and concluded that "LSD is revealed as a potential therapeutic agent in psychiatry". ❖ Fuentes asserts that to pave the way for future advancements, more studies adhering to contemporary standards are necessary.

General Findings

Neurological processes of LSD

As noted by West, LSD affects the activity of the central nervous system, switching towards an alert or arousal pattern (103). The mentioned shift is crucial in understanding how the substance influences perception, cognition, and behaviour. LSD is a 5-HT_{2A} serotonin receptor agonist (Liechti 2115). In other words, the drug is increasing the neurotransmission of serotonin as well as dopamine. The 5-HT_{2A} serotonin receptor, a subtype of the serotonin receptor heavily involved in emotional processing, was studied extensively and brought scientists to the conclusion that it reduces anxiety and depression-related behaviour in animals (Fuentes). As highlighted by Dos Santos, the anti-addictive properties of LSD can be attributed to the activation of the dopaminergic system and stimulation of the neural pathways (205). According to Bogenshutz, the 5-HT2A serotonin receptor, linked to changes in perception and cognition, is thought to play a role in the neuroplastic changes, such as dendritic remodelling, that could underlie the long-term therapeutic effects of classic hallucinogens (255). LSD has the ability to restore dopaminergic homeostasis in the mesolimbic dopamine pathway, reducing the reinforcing properties of addictive substances, though its effects are significantly impacted by the environment in which it is administered. Therefore, lysergic acid diethylamide alters the neural framework and indirectly enhances dopamine neurotransmission (Liechti 2116). Further trials are needed to evaluate the efficacy of LSD on alcohol addiction fully.

Empirical data

The benefits of LSD-assisted psychotherapy and its significant potential in treating alcohol dependency disorder have been depicted in several studies from the 1950s and 1960s and reevaluated in modern times (Frood, Bryce, Bogenshutz and Johnson, Fuentes et al., Liester, Nutt, West, Winkelman). As highlighted by Frood, the research landscape of the time period on the drug-assisted psychotherapy shows potential validity and relevance in contemporary scientific discussions, whereas, most of the conducted studies from these decades cannot be considered, as they fail to be reliable in the present.

A valid survey conducted by Bryce on 149 patients, who underwent LSD treatment for alcoholism, revealed that 19 respondents experienced benefits from the therapy, indicating a

potential positive impact of LSD in treating alcoholism (77). Frood examined the outcomes of six trials involving 536 participants. Remarkably, 59% of those receiving LSD reported lower levels of alcohol misuse, a significant improvement compared to 38 % in the placebo control group. Psychedelics like LSD are able to address deficiencies commonly found in addicts. Winkelman characterises the alteration of consciousness induced by psychedelics as "psychointegration", which involves the integration of emotional, sensory, and improved outcomes compared to 38% in the control group (109, Bogenshutz and Johnson 256). To support the theory, Fuentes et al. conducted a retrospective analysis of LSD research, and concluded that "LSD is revealed as a potential therapeutic agent in psychiatry". Developing the idea of Fuentes, Ludwig A et al. showed substantial improvement of patients for each period of 6 and 12 months by Behaviour Rating scale. These findings represent the beginning of a deeper exploration into the therapeutic potential of the psychedelic in treating complex conditions like alcoholism. A more recent analysis of randomised controlled trials indicated significant short-term and medium-term reductions in alcohol abuse following a single dose of LSD. However, these effects tended to diminish by the 12 month follow-up.

Nutt claims that the appearance of clinical research on psychedelics, detailed by Liester et al., comes after decades of bans that halted promising research in the 1960s (142, 151). These substances show potential in treating various psychiatric conditions. West claims that "clinical research on LSD as a treatment must go on", as he acknowledged potential benefits that only could be studied through research. Matthew Johnson emphasises the necessity of testing of LSD in "new, well-designed and rigorous trials", overcoming methodological shortcomings of earlier research and in providing evidence-based conclusions about LSD's effectiveness as a treatment option (Frood). Fuentes asserts that in order to "open new doors in the future more studies under contemporary standards are needed". Experts in the field argue for LSD's continued research, implying the need for reclassification.

Discussion

Interpretations and implications

LSD's intricate interactions with the human brain, which provide a comprehensive understanding of its effects, underscore the need for the drug's reclassification in the purposes of research. LSD's interactions with the neurotransmitter systems highlight their complex relationship and present an area for ongoing research and discussion in the scientific community.

Findings related to LSD's mechanism of action provide the rationale for considering psychedelics in the modulating of mood and behaviour, making it interesting in the context of exploring therapeutic treatments for mental health problems in humans. Dopamine plays a key role in fixed ratio reinforcement occurring in AUD, as detailed by Di Chiara. As the primary reason for alcohol use disorder lies in the emotion regulation through dopamine release, the comprehensive understanding of LSD's interactions with both serotonin receptors and the dopaminergic system is critical for addressing the disease (Alcohol and Dopamine).

Neurotransmitting systems are central to emotional processing and regulation, impacting behaviours associated with alcohol dependency.

LSD often induces profound, transformative experiences, namely spiritual or transcendental, that can alter an individual's worldview and self-perception. A significant shift occurs in attitudes and behaviours, particularly in relation to substance dependence. For individuals struggling with alcoholism, such profound perceptual and spiritual shifts facilitated by LSD may result in a reevaluation of their relationship with alcohol, potentially aiding in breaking the cycle of dependency and leading the way towards recovery and sober life (Dyck 318). The studies included in this paper suggest the potential efficacy of LSD in reducing alcohol dependence and misuse, underscoring the hallucinogen's contribution into behavioural change and unwillingness to drink again.

Considerations

Limited body of knowledge

In modern reviews and analyses, researchers advocate for the prolonging of the LSD studies. Nonetheless, earlier scientists' research came under scrutiny as it found little reliable evidence of LSD benefits. Bryce carried out his research in the context of chronic alcoholism, though he found no clear evidence that LSD was more effective than other treatments (78). The famous Saskatchewan studies on LSD's anti addictive properties were questioned as they lacked methodological validity and reliability, where the historical context of research could impact the study design and interpretation (Dyck 325). The existing body of knowledge is compromised, which implies potential impediments to experiments. However, such an undefined profile of LSD urges to facilitate further research. Modern experts of the review present a unified call for more clinical tests and suggest not giving up the idea of LSD positive clinical effects study.

Physiological risks

While exploring the positive side of LSD experiences, it is of utmost importance to take into account the potential risks. Researchers in the field of psychedelic therapy, such as Fuentes, have brought to light several critical aspects regarding the use of the hallucinogen. Their statements emphasise the potential challenges of a "bad trip", characterised by intense anxiety and confusion in uncontrolled environments, which underscores the importance of controlled and supportive settings for LSD use. Nonetheless, the concern is balanced by the recognition of the drug's favourable therapeutic index and the assertion that LSD can be used safely in controlled settings with a potentially lower toxicity compared to other drugs. According to Rucker, the therapeutic index for LSD is around a thousand, which is a ratio of toxic dose per standard (2902). The figure is relatively high compared to cocaine (15) and for alcohol (10). LSD, while powerful in its psychoactive effects, is "less toxic or harmful than most licit and illicit drugs", as noted by Dos Santos (198). However, the psychological risks and the importance of dosage, setting and guidance remain critical considerations in LSD-assisted psychotherapy.

Ethical concerns

Nowadays, researchers collectively propose an idea that by aligning LSD research with current scientific practices and norms, the potential benefits can be explored ethically. Although the scientific community advocates for LSD's implementation in fields of research, the current perception of LSD's role is limited by its controversial public image. The substance's widespread recreational use and the negative portrayal by government propaganda have contributed to the formation of a stigma. Consequently, reclassification of LSD is very likely to face substantial criticism regarding the ethics of the decision. For future directions, it is essential to change the perspective of society on the hallucinogen and the therapeutic potential the hallucinogen holds.

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Effective Heritable Strategies to Eliminate Mosquito-Borne Diseases By Aradhana Sekar

Abstract

Mosquito-borne diseases pose a significant threat to global public health, especially in warm and humid regions. Diseases such as malaria, dengue fever, Zika virus, and chikungunya continue to spread to vulnerable global communities in high-risk areas. This review will summarize effective interventions to mitigate the impact of mosquito-borne diseases on populations worldwide. Along with current everyday solutions, using heritable next-generation technology such as deactivating mosquito sperm, converting mosquito sex, Wolbachia bacteria-laced mosquitoes, and targeting disease carriers using CRISPR can minimize danger as much as possible. By addressing this issue and gaining knowledge through a comprehensive review of strategies that can be used, a safer and healthier future can be achieved for individuals around the world. Advancements of suitable methods, as well as public awareness of the problem, can contribute to international cooperation and improved quality of life for several regions worldwide. By especially empowering communities with knowledge, there is potential to lessen the threat of this issue and build resilient defenses. Understanding the multifaceted aspects and socio-economic challenges posed by vector-borne diseases is imperative to collectively implement evidence-based methods in certain areas. Continued research and investment in the development of innovative approaches ensure the best possibilities for improved global health.

Keywords/Index Terms

Animal Sciences, Genetics, Transgenics, Vector-Borne Disease Prevention, Mosquito Control.

Introduction

Issue

Mosquitoes are the deadliest predators of human beings on the planet, contributing to at least 700,000 human deaths annually (6 Mosquito Diseases That Can Be Deadly | Pfizer; Dueck). With more than 100 trillion mosquitoes swarming the Earth, they outnumber humans by almost 16,000 to one (Dueck). Mosquito-borne diseases are easily transferred to humans through their bites, and with every mosquito bite, there is the risk of serious disease-causing symptoms such as itching, fever, headache, and muscle weakness or pain (6 Mosquito Diseases That Can Be Deadly | Pfizer; “Mosquito-Borne Diseases”; “Mosquito Bites”; Mosquito-Borne Diseases | NIOSH | CDC). Female mosquitoes are primarily responsible for this risk, taking blood meals from their hosts to produce eggs (“Mosquitoes with Wolbachia | CDC”; “Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control”). Unlike their female counterparts, male mosquitoes feed on nectar and are non-biting, meaning they do not directly contribute to the transmission of viruses, bacteria, parasites, etc (“Mosquitoes with Wolbachia | CDC”). Diseases such as Zika fever, West Nile virus, chikungunya virus, dengue,

and malaria are typically transmitted by three genera of mosquitoes - Aedes, Culex, and Anopheles (Table 1) (“Mosquito-Borne Diseases”; Mosquito-Borne Diseases | NIOSH | CDC; Kumar et al.).

Aedes mosquitoes, identified by their black and white markings on the body, are primarily active during the daytime, with the greatest number of bites occurring in the early morning as well as evening before dusk (Table 1) (“Mosquito-Borne Diseases”). Aedes aegypti and Aedes albopictus are the two distinct species of Aedes that are vectors of many viruses Aedes aegypti, commonly referred to as the yellow fever mosquito, is often found in urban areas, both indoors and outdoors, and relies on humans as its main source of blood (“Mosquito-Borne Diseases”). Aedes albopictus, also known as the Asian tiger mosquito, is found in outdoor areas of vegetation and relies on animals (domestic and wild), as well as humans for blood (“Mosquito-Borne Diseases”). Due to the prevalence of Aedes aegypti mosquitoes near human areas, they pose a greater threat and are more likely to spread diseases than Aedes albopictus mosquitoes (“Mosquito-Borne Diseases”). They are found in tropical and subtropical areas, with Aedes albopictus mosquitoes residing further north than Aedes aegypti as a result of their ability to survive colder temperatures (“Mosquito-Borne Diseases”).

Culex mosquitoes are common house mosquitoes that are found both indoors and outdoors (“Mosquito-Borne Diseases”). They feed at night and rely on humans and animals for their blood supply (“Mosquito-Borne Diseases”). Culex mosquitoes are dispersed worldwide and reside in tropical, temperate regions - apart from extreme northern latitudes (“Mosquito-Borne Diseases”).

Anopheles mosquitoes can be found both indoors and outdoors, and are often active between sunrise and sunset (“Mosquito-Borne Diseases”). Females can feed on both humans and animals, but certain species have preferences for either (“Mosquito-Borne Diseases”). Although they can transmit other diseases, the species that prefer feeding on humans are popularly recognized for spreading malaria, and pose a great risk in areas where they are prominent (Table 1) (“Mosquito-Borne Diseases”).

Over time, more vaccines and specific medications have been developed to treat and protect people in high-risk areas from disease (Wiwanitkit). For the purpose of this review, heritable methods will be defined as methods that affect multiple generations of mosquitoes, or reduce disease transmission of population suppression happening through inheritance. By harnessing natural mosquito reproduction alongside sophisticated genetic technologies, heritable traits can be developed that are crucial to curbing the prevalence of these diseases through reduced disease transmission and population suppression. This paper will focus on the direct methods of prevention which target mosquitoes. It will provide a comprehensive overview of the common current methodologies, as well as evaluate heritable next-generation genetic engineering methods that hold promise for improved efficiency.

Table 1: The three genera of mosquitoes (Aedes, Culex, and Anopheles) and the diseases they each carry and spread.

	Visual	Diseases Spread
Aedes		Viral: Zika, dengue, chikungunya, yellow fever, Rift Valley disease, etc. Parasitic: Lymphatic filariasis, etc.
Culex		Viral: West Nile fever, St. Louis encephalitis, and Japanese encephalitis, viral diseases of birds and horses, etc. Parasitic: Lymphatic filariasis, etc. Bacterial: Tularemia, etc.
Anopheles		Parasitic: Malaria, Lymphatic filariasis, etc.

Ineffective Solutions

Some of the most common everyday solutions include using simple mosquito repellents, fans, bed nets, attractive toxic sugar bait (ATSB), or mosquito trappers that electrocute and kill mosquitoes ("Mosquito Bites"; Kumar et al.). These attract-and-kill type solutions, such as ATSB, are very temporary and can only reduce the transmission of diseases to a limit (Kumar et al.). Mosquito control agencies use mosquito surveillance to monitor the amount, type, and sources of mosquitoes in some areas (Kumar et al.; "What Mosquito Control Programs Do | CDC"). This can help in some areas but is not very effective in places that require surveillance in larger areas, such as regions in Brazil, Indonesia, Malaysia, and Thailand, which have very high risks for diseases such as dengue, and contain the highest number of mosquito species in the world (Figure 1) (Dueck; Kumar et al.; "What Mosquito Control Programs Do | CDC"). Mosquitoes are generally found in humid areas with water to lay their eggs, which many warm, tropical countries accommodate - making the risk areas in these countries higher (Figure 1) (Dueck; Mosquito-Borne Diseases | NIOSH | CDC). Marshes, grasslands, forests, or urban environments are common areas where they are found as well (Dueck). Another commonly used method is spraying adulticides, which kill the adult mosquitoes in a given population (Kumar et al.; "What Mosquito Control Programs Do | CDC"). Not only is this method environmentally detrimental, but some diseases are also known to be passed to mosquito offspring as well, meaning that killing only adult mosquitoes may not end outbreaks (Kumar et al.; "Female Mosquitoes Can Transmit Zika Virus to Their Eggs, Offspring"). For example, evidence suggests

that female mosquitoes can transmit viruses to their eggs and offspring, such as Zika, dengue, and yellow fever, etc ("Female Mosquitoes Can Transmit Zika Virus to Their Eggs, Offspring").

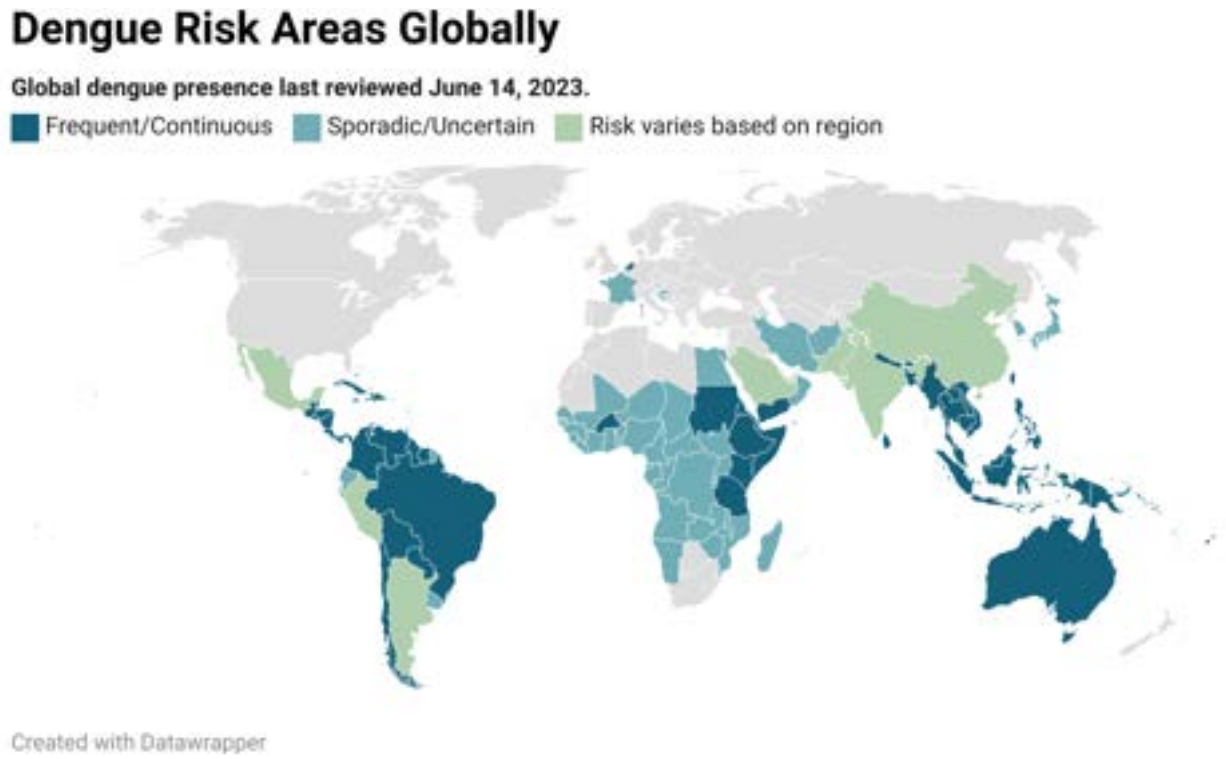

Figure 1: Worldwide dengue risk from mosquitoes living in altitudes below 6,500 feet. Data adapted from the CDC, last reviewed June 14, 2023 ("Dengue Areas of Risk Around the World | CDC").

Current Sterile Insect Technique (SIT)

Despite significant efforts to control mosquito populations, most traditional methods have yet to display long-lasting results. One method currently in use, however, has proven to be more comprehensive than others. The method, named the sterile insect technique (SIT) is a control strategy developed to produce sterile adult insects (Sterile Insect Technique; Bourtzis and Vreysen). It has been used on several insect populations, such as different subspecies of fruit flies, moths, and mosquitoes (Sterile Insect Technique; Bourtzis and Vreysen). The process of irradiation, utilizing gamma rays or X-rays is used to produce genetic mutations or chromosomal breaks, that can ultimately lead to infertility in insects (Figure 2) (Sterile Insect Technique; Bourtzis and Vreysen). A common 4-step approach is used to conduct this method (Kumar et al.). It starts with the mass production of mosquitoes, sorting males from the females, irradiating the male mosquitoes (to eliminate reproduction), and finishes with the mass release of the sterilized insects into a target area (Figure 2) (Kumar et al.). The release of the sterilized mosquitoes will suppress the current population with lowered reproduction rates as the sterile males try to mate with females (Kumar et al.; Sterile Insect Technique; Bourtzis and Vreysen).

This eventually leads to the eradication of the entire population as no offspring is produced (Figure 2) (Sterile Insect Technique; Bourtzis and Vreysen; Kumar et al.). Although this strategy has been popularly recognized as environmentally cautious and more efficient than other control strategies, it was later observed that insects subjected to radiation to achieve sterilization often develop chromosomal damage, which reduces their viability in the wild ("Combating Mosquito-Borne Diseases with CRISPR"; Chen et al.). Another standard limitation resulting from this method is the inability of insects to reproduce in the wild (Kumar et al.; Chen et al.). The fitness and reproduction of insects are significant factors in the ultimate goal of achieving maximum population suppression (Kumar et al.; "Combating Mosquito-Borne Diseases with CRISPR"; Chen et al.). Exploring the depths of more innovative approaches is crucial to interrupt the ongoing transmission of these diseases.

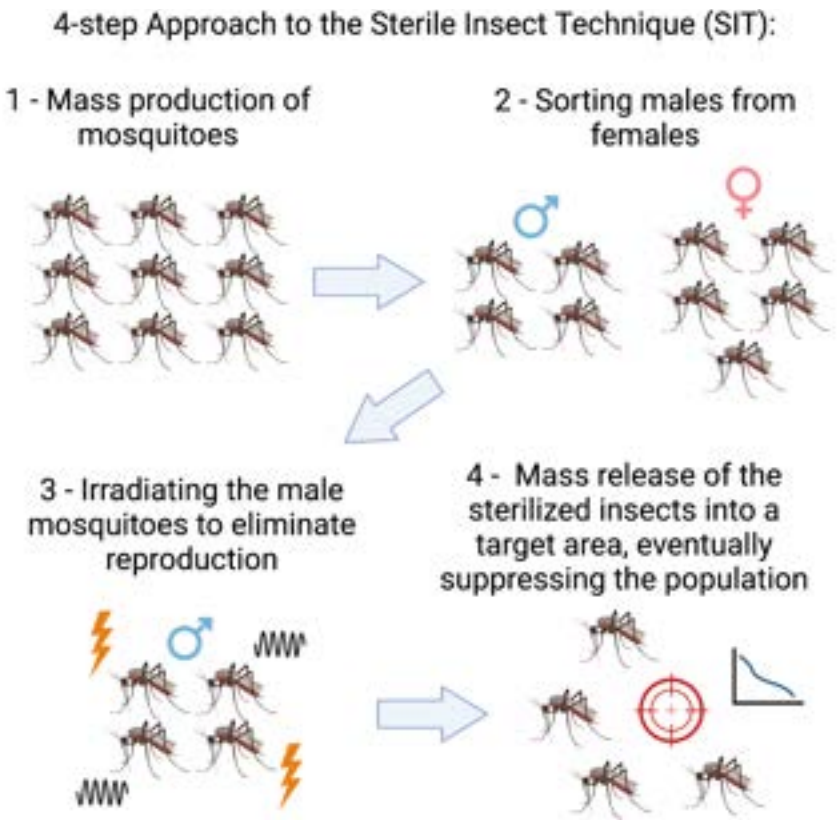

Figure 2: 4-step approach to the sterile insect technique - starting with the mass production of mosquitoes, sorting males from females, irradiating the male mosquitoes to eliminate reproduction, and finally, the mass release of sterilized insects into a target area, eventually suppressing the population.

Discussion/Next-Generation Solutions

Deactivating Mosquito Sperm

A study investigating the proteins responsible for activating mosquito sperm suggests that the fertilization process can be stopped when these proteins are shut down ("Humans Bite Back by Deactivating Mosquito Sperm"). Given the transmission of diseases from female mosquitoes to humans through bites, this method can reduce the number of fertile non-biting males in a population, restraining the population from increasing and producing more female mosquitoes ("Humans Bite Back by Deactivating Mosquito Sperm"). This method has been used on Culex mosquitoes, the common house mosquitoes that carry many life-threatening viruses such as West Nile fever, brain-swelling encephalitis (St. Louis/Japanese), the parasitic disease lymphatic filariasis, the bacterial disease tularemia, etc ("Humans Bite Back by Deactivating Mosquito Sperm"; "Mosquito-Borne Diseases"). During mating, mosquitoes link from tail to tail, and the males transfer their sperm into the female reproductive tract ("Humans Bite Back by Deactivating Mosquito Sperm"; Degner and Harrington). It is possible for the sperm to be stored there but to continue to the step of fertilization, it has to move through the tract ("Humans Bite Back by Deactivating Mosquito Sperm"; Degner and Harrington). To complete this process and successfully move through the tract, there are specialized proteins secreted during ejaculation ("Humans Bite Back by Deactivating Mosquito Sperm"). These calcium channel proteins activate the movement of the sperm to power them through the tract using their flagella (tails) ("Humans Bite Back by Deactivating Mosquito Sperm"). Without these proteins present, the sperm will not be able to reach or penetrate the eggs in the female, and after remaining immobile for some time, the sperm will eventually degrade ("Humans Bite Back by Deactivating Mosquito Sperm"). The technology that targets these proteins is 100% effective in immobilizing the sperm of the treated mosquitoes, and the focus of this approach is to control mosquito populations rather than eradicate them (Figure 3) ("Humans Bite Back by Deactivating Mosquito Sperm"). In other words, instead of eliminating mosquito populations as a whole using pesticides, this strategy will shift the proportion of fertile to infertile males, suppressing the population (Figure 3) ("Humans Bite Back by Deactivating Mosquito Sperm"). Many ecologists believe that despite the magnitude of dangers mosquitoes exhibit, completely eradicating these populations might be unwise ("Humans Bite Back by Deactivating Mosquito Sperm"). Not only do pesticides have unintended effects that might destroy both beneficial and harmful aspects of the environment, but mosquitoes also play an important role in the food chain for many other organisms ("Humans Bite Back by Deactivating Mosquito Sperm"). Although this approach is not necessarily heritable, it targets the aspect of mating and is an efficient alternative to other mosquito control methods (Figure 3) ("Humans Bite Back by Deactivating Mosquito Sperm"). The team hopes that this method may have other implications, and the discovery of the sperm motility regulators in the Culex mosquitoes is the first step in the right direction ("Humans Bite Back by Deactivating Mosquito Sperm").

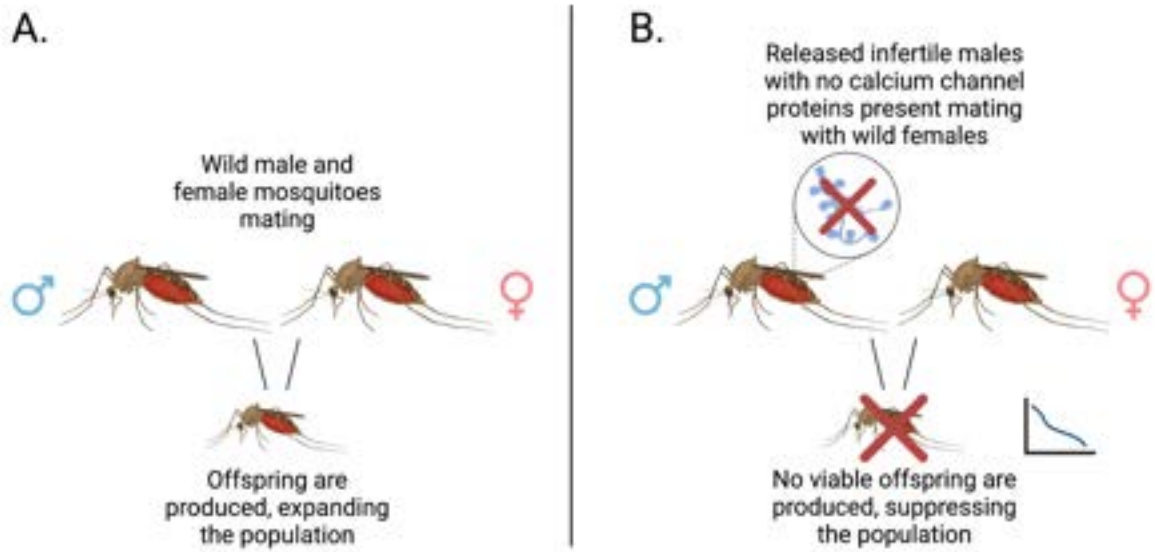

Figure 3: Wild mosquitoes mating compared with lab-released infertile males mating with wild females. (A) Wild mosquitoes mate, resulting in the expansion of the population through produced offspring. (B) Infertile males containing no calcium channel proteins to activate sperm movement mating with wild females, resulting in no viable offspring and suppression of the population.

Converting Mosquito Sex

Mosquito research scientists have proved that it is possible to convert female mosquitoes into fertile male mosquitoes by genetically altering a single gene, reducing the transmission of diseases (Kumar et al.; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"; Chen et al.; Aryan et al.). Male mosquitoes, unlike females, are unable to transmit pathogens to humans through their bites ("Mosquitoes with Wolbachia | CDC"; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"). Contrarily, female mosquitoes are the primary carriers of the pathogens that result in thousands of human deaths from diseases annually, as they require blood to produce eggs ("Mosquitoes with Wolbachia | CDC"; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"). By reducing the ability to transmit diseases and bite, while also suppressing the proportion of males to females in the population, there is great potential to heavily reduce the spread of mosquito-borne diseases as well (Kumar et al.; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"; Chen et al.; Aryan et al.). This approach is a subset of the sterile insect technique that relies on mating, and it has been tested on Aedes aegypti mosquitoes, commonly found in urban areas (Kumar et al.; "Mosquito-Borne Diseases"; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"; Chen et al.; Aryan et al.). These mosquitoes carry many viral diseases, including Zika, dengue, chikungunya, yellow fever, and Rift Valley disease ("Mosquito-Borne Diseases"). Similar to the Y chromosome in humans, there is a male-determining locus (M locus) in mosquitoes (Figure 4) (Kumar et al.;

"Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"; Chen et al.; Aryan et al.). This locus determines the male sex in mosquitoes and is only inherited by the male offspring (Kumar et al.; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"; Chen et al.; Aryan et al.). Nix, a male-determining gene, lies within the M locus, and the insertion of this gene into female mosquitoes results in the conversion to fertile males (Figure 4) (Kumar et al.; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"; Chen et al.; Aryan et al.). The M locus also contains around 30 genes, and one of them named myo-sex is needed for male flight (flight is needed for mating) (Kumar et al.; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"; Chen et al.; Aryan et al.). In addition to the Nix gene, researchers had to insert the myo-sex gene into the females in order for them to fly and reproduce (Kumar et al.; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"; Chen et al.; Aryan et al.). This sex conversion was found to be highly stable over many generations in the laboratory (Kumar et al.; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"; Chen et al.; Aryan et al.). These characteristics will be inherited for generations, and the offspring of the mosquitoes containing the CRISPR-targeted male-sterile mutation will be exclusively male, eventually diminishing the population (Figure 4) (Kumar et al.; "Researchers Convert Female Mosquitoes to Nonbiting Males with Implications for Mosquito Control"; Chen et al.; Aryan et al.).

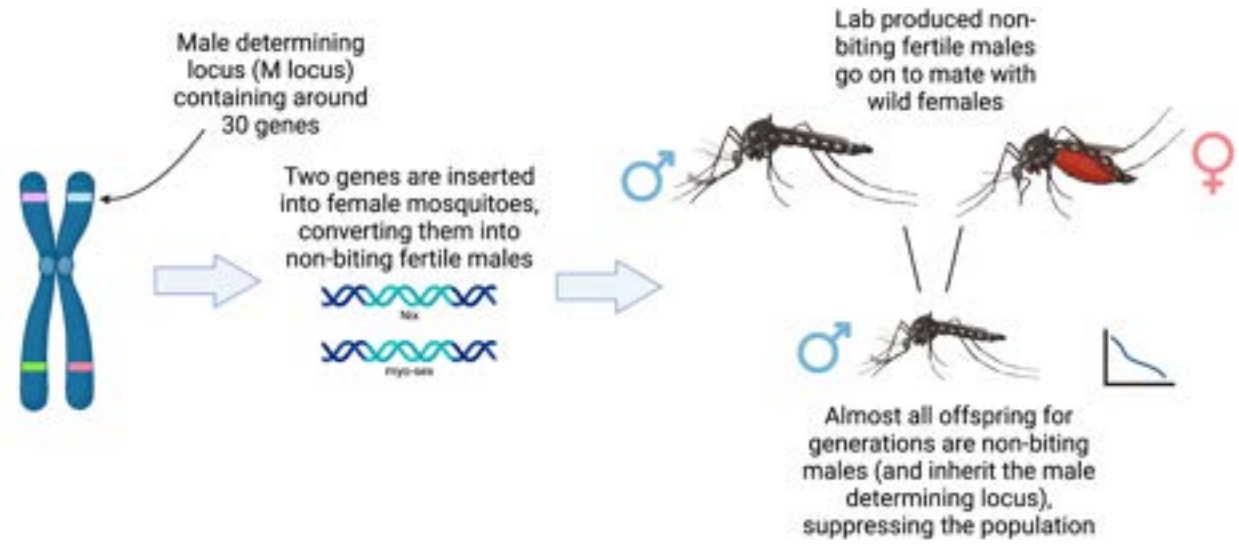

Figure 4: Process of converting fertile females into infertile non-biting males, through the insertion of the Nix and myo-sex genes to suppress the population.

Wolbachia Bacteria-Laced Mosquitoes

Researchers are working to limit the spread of dengue using mosquitoes laced with a bacteria called Wolbachia pipientis ("Mosquitoes with Wolbachia | CDC"; Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit

Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; Macias et al.). This bacteria has been used on Aedes aegypti mosquitoes so far—the species responsible for passing on many diseases (mentioned above) ("Mosquitoes with Wolbachia | CDC"; Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; Macias et al.). This method has two objectives: population suppression and reducing the transmission of the dengue virus (Figure 5, 6) ("Mosquitoes with Wolbachia | CDC"; Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; Macias et al.). Following the introduction of Wolbachia into mosquito eggs, researchers opt to release the males into the environment, as they cannot effectively reproduce with Wolbachia-free females (Figure 5) ("Mosquitoes with Wolbachia | CDC"; Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; Macias et al.). This strategic approach leads to the suppression of the mosquito population ("Mosquitoes with Wolbachia | CDC"; Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; Macias et al.). Scientists control the number of mosquitoes released depending on the risk of the area ("Mosquitoes with Wolbachia | CDC"; Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; Macias et al.). For example, six Wolbachia mosquitoes are released each week for every person living in high-risk areas in Singapore ("Bacteria-Laced Mosquitoes Limit Spread of Dengue"). Additionally, when a strain of Wolbachia is introduced to mosquito eggs, it has proven to reduce the transmission of the dengue virus and in turn, reduces the spread by 77% when infected into mosquitoes (Figure 6) ("Mosquitoes with Wolbachia | CDC"; Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; Macias et al.). However, scientists don't know the exact mechanism through which Wolbachia reduces dengue transmission ("Combating Mosquito-Borne Diseases with Bacteria"). Dengue takes over the machinery of the host cells, replicates, and then sprouts or bursts out of the cell ("Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"). When infected with the bacteria, the virus could not replicate or infect mosquito cells as efficiently (Figure 6) ("Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"). This technology has been used on

populations in (but not limited to) Indonesia, Vietnam, Brazil, Singapore, Thailand, Mexico, Australia, Colombia, and parts of the United States ("Mosquitoes with Wolbachia | CDC"; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; Macias et al.). The bacteria is self-spreading, meaning if female-laced mosquitoes are released they can go on to mate with local populations and transfer the bacteria to generations of offspring (Figure 5) (Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; Macias et al.). This is efficient, as it opens the scope to wide populations of mosquitoes (Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; Macias et al.). The progeny of Wolbachia-containing females also obtain the bacteria through transmission, and as a result, each generation continually has more mosquitoes containing Wolbachia (Figure 5) (Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"; Macias et al.). While this method has shown promising results, it might not always be effective because larger mosquito populations may point to more opportunities for the virus to develop resistance to Wolbachia ("Combating Mosquito-Borne Diseases with Bacteria"). Despite this fact, experiments found that the evolution to resistance to Wolbachia is difficult, making this possibility unlikely ("Combating Mosquito-Borne Diseases with Bacteria"). However, there is a possibility that the life span of laced mosquitoes can almost be halved due to a decrease in mosquito fitness (Kumar et al.). This method has only targeted dengue so far, but the same bacterial technique holds the potential to limit transmission of other diseases spread by mosquitoes, including Zika, chikungunya, malaria, and yellow fever, and reduce the spread of diseases that are very prevalent in other places (Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes").

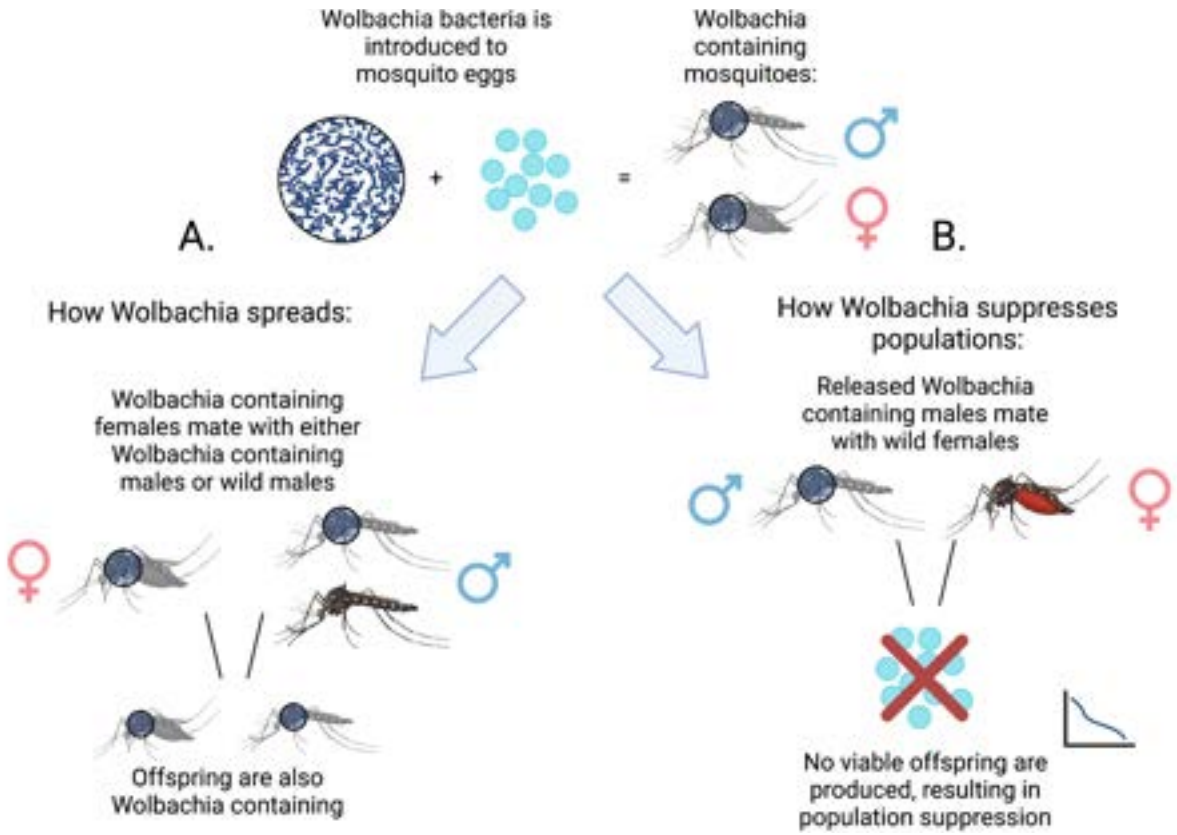

Figure 5: Process by which Wolbachia is transmitted among mosquitoes after being introduced to mosquito eggs, and how releasing Wolbachia-laced mosquitoes suppresses populations. (A) Offspring of Wolbachia containing females also contain Wolbachia. (B) Wolbachia-containing males that are introduced to populations are unable to mate and produce viable offspring with wild females, suppressing the population.

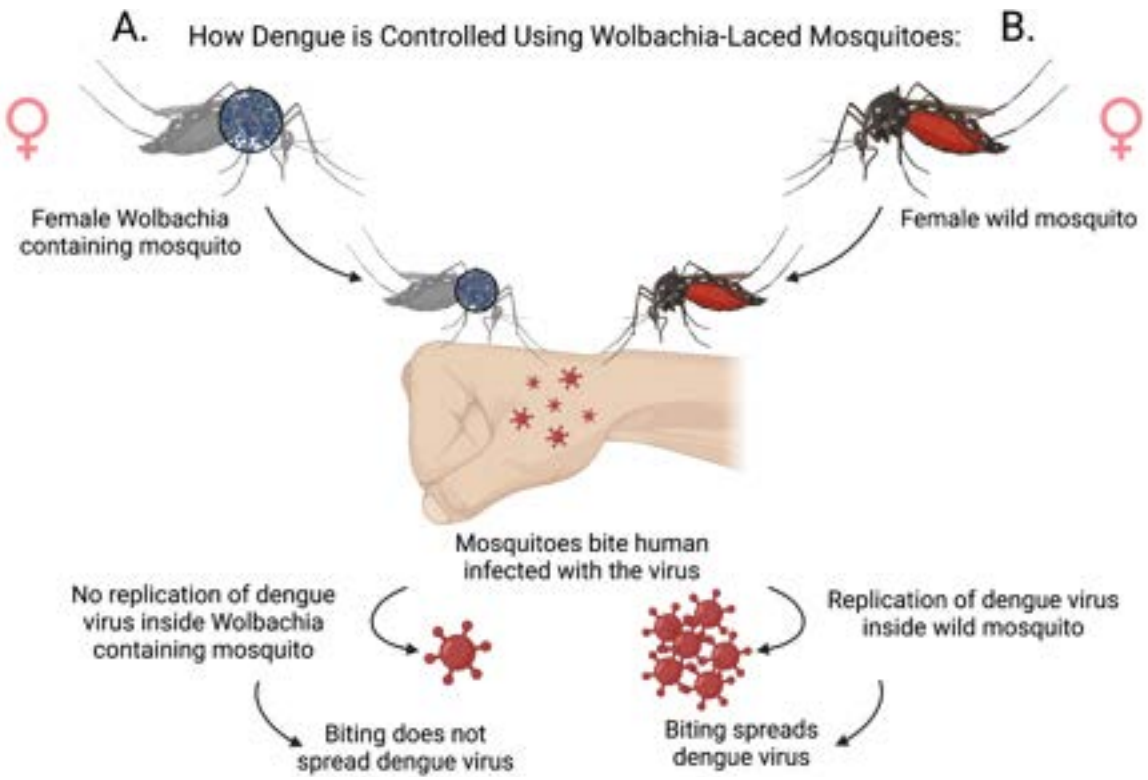

Figure 6: Comparison between a female Wolbachia-containing mosquito and a female wild mosquito. (A) The mechanism by which dengue is controlled through reduced replication of the virus in Wolbachia-laced mosquitoes. (B) Mosquitoes with no Wolbachia present, replicating and spreading the virus.

Targeting Disease Carriers Using CRISPR

Clustered Regularly Interspaced Short Palindromic Repeats or CRISPR, is an efficient gene editing tool that can be used to cut nucleic acids at a specific site and target DNA ("Combating Mosquito-Borne Diseases with CRISPR"; Bui et al.). To accomplish this, a guide RNA binds to a specific site and recruits a nuclease (usually Cas9) that cuts there ("Combating Mosquito-Borne Diseases with CRISPR"). Among the many applications of CRISPR, it can be used to block viral transmission of diseases ("Combating Mosquito-Borne Diseases with CRISPR"). It is a relatively safer insect control alternative compared to insecticides, and gaining public authorization and general acceptance might be more achievable in contrast to other methods ("Combating Mosquito-Borne Diseases with CRISPR"). It holds potential for breakthroughs in other technologies, such as mosquito surveillance ("Combating Mosquito-Borne Diseases with CRISPR"). When an insect is infected with a pathogen, scientists can now detect it and diagnostics can be developed ("Combating Mosquito-Borne Diseases with CRISPR"). There are many applications of CRISPR that can help prevent the transmission of diseases ("Combating Mosquito-Borne Diseases with CRISPR"). While these applications have only been performed on Aedes aegypti mosquitoes, which pose the greatest risk to humans due to their prevalence in populated urban areas, there is a promising opportunity for this technology

to expand to target other types of mosquitoes as well (“Combating Mosquito-Borne Diseases with CRISPR”).

Using a technology called REAPER (vRNA Expression Activates Poisonous Effector Ribonuclease), CRISPR ribonucleases are programmed to target viruses and degrade RNA instead of DNA (Figure 7) (“Combating Mosquito-Borne Diseases with CRISPR”; Benetta et al.). Mosquitoes are engineered to express CRISPR ribonucleases and design guides that target different viruses (Figure 7) (“Combating Mosquito-Borne Diseases with CRISPR”; Benetta et al.). When a mosquito gets infected with a virus, CRISPR cuts the viral RNA sequences, either resulting in the mosquito successfully no longer containing the virus, or the mosquito’s fitness being harmed due to collateral cleavage, and the mosquito ultimately dying (Figure 7) (“Combating Mosquito-Borne Diseases with CRISPR”; Benetta et al.). There are hopes to advance the CRISPR machinery to target all mosquito-borne diseases humans are at risk of (“Combating Mosquito-Borne Diseases with CRISPR”; Benetta et al.).

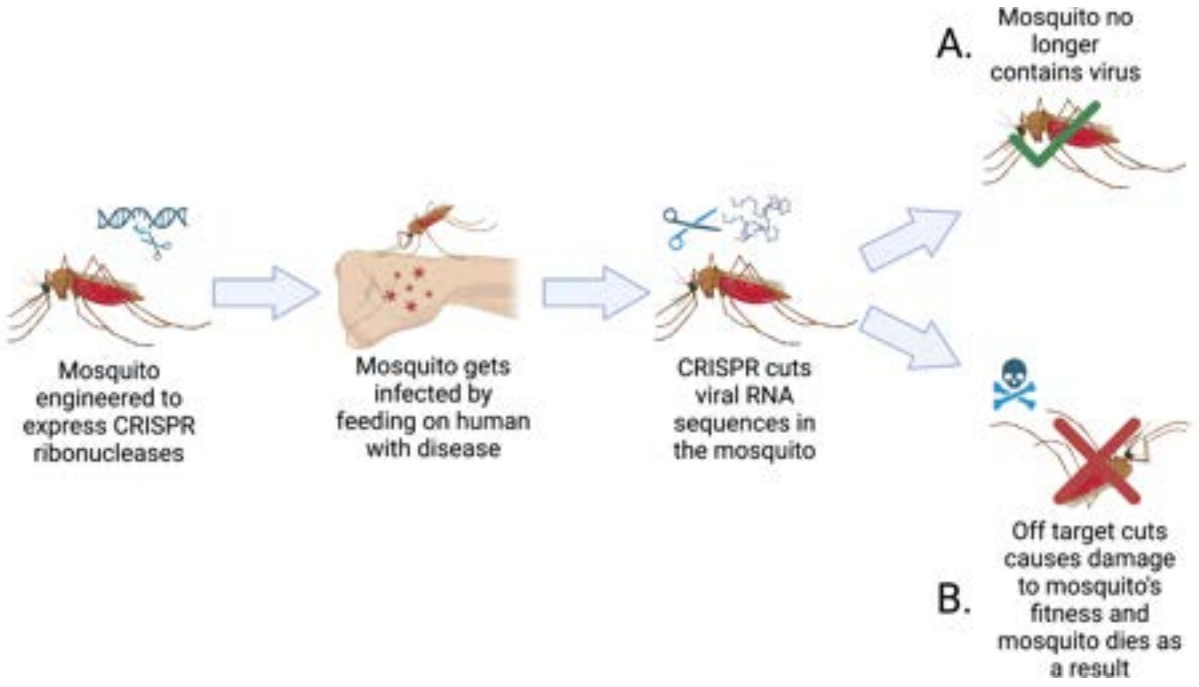

Figure 7: Process of CRISPR machinery cutting viral RNA sequences in a mosquito infected with a virus. (A) This either results in the mosquito successfully no longer containing the virus, or (B) the fitness being damaged due to off-target cuts, killing the mosquito.

Another tried method utilizes CRISPRa (“Combating Mosquito-Borne Diseases with CRISPR”; Bui et al.). CRISPRa, which uses an inactive version of Cas9 (dCas9) is used to achieve complete lethality in insects by overexpressing developmental genes (Figure 8) (“Combating Mosquito-Borne Diseases with CRISPR”; Bui et al.). It cannot cut DNA, but using guide RNAs it continually binds to targets and promotes gene expression by using transcriptional machinery to the target promoter region (Figure 8) (“Combating Mosquito-Borne Diseases with

CRISPR"; Bui et al.). By keeping CRISPRa inactive, scientists were able to maintain an engineered mosquito line through an innovative genetic crossing design ("Combating Mosquito-Borne Diseases with CRISPR"; Bui et al.). CRISPRa activates and causes lethality when crossing the mosquitoes with non-engineered insects that have the targets present, and this creates no viable offspring (postzygotic isolation) (Figure 8) ("Combating Mosquito-Borne Diseases with CRISPR"; Bui et al.). In addition, scientists were able to transactivate the positive transcriptional regulator gene of the Toll immune pathway called AaRel1, which made mosquitoes better able to repress dengue (Bui et al.). This is a groundbreaking passage to discovering more genetic control strategies in the future ("Combating Mosquito-Borne Diseases with CRISPR"; Bui et al.). Initially, flies were used for experimentation and genetic encoding to test the efficiency of CRISPR, with the objective of crossing them together ("Combating Mosquito-Borne Diseases with CRISPR"). After discovering the dexterity and versatility CRISPR possesses, flies were successfully used again to test the CRISPRa theory ("Combating Mosquito-Borne Diseases with CRISPR"). The theory was then finally tested in Aedes aegypti mosquitoes, again yielding successful results ("Combating Mosquito-Borne Diseases with CRISPR").

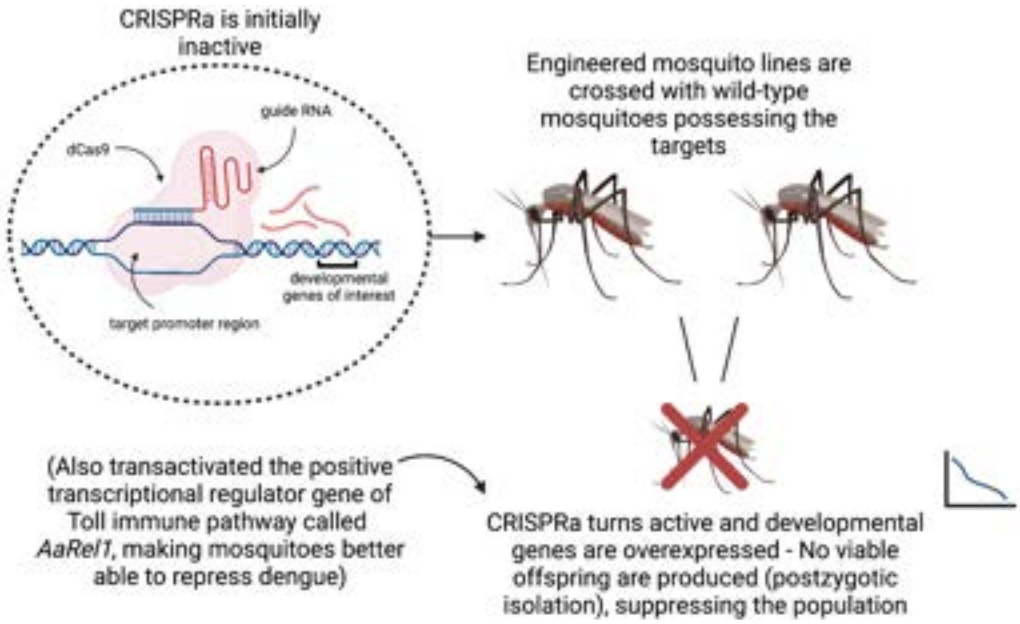

Figure 8: Function of CRISPRa in programmed mosquitoes, as well as process to transactivation of developmental genes, including AaRel1. When CRISPRa turns active and developmental genes are overexpressed, the population is suppressed as a result of postzygotic isolation.

In another more reliable application, scientists were able to reduce reproduction by first making different insect lines homozygous for cas9 and a guide RNA that is designed to target genes important for female development and male fertility ("Combating Mosquito-Borne Diseases with CRISPR"; Chen et al.). Through Mendelian segregation, offspring receive both the cas9 gene and guide RNAs when crossing these lines together (Figure 9) ("Combating

Mosquito-Borne Diseases with CRISPR"; Chen et al.). Targeting those genes using CRISPR results in the death of all females and the sterilization of all males (Figure 9) ("Combating Mosquito-Borne Diseases with CRISPR"; Chen et al.). Females transmit diseases, making this step essential to controlling insect populations ("Combating Mosquito-Borne Diseases with CRISPR"; Chen et al.). Releasing the sterile male offspring in the environment to hatch would cause the population to gradually decline as the sterile males try to mate with females, but no progeny is produced (Figure 9) ("Combating Mosquito-Borne Diseases with CRISPR"; Chen et al.).

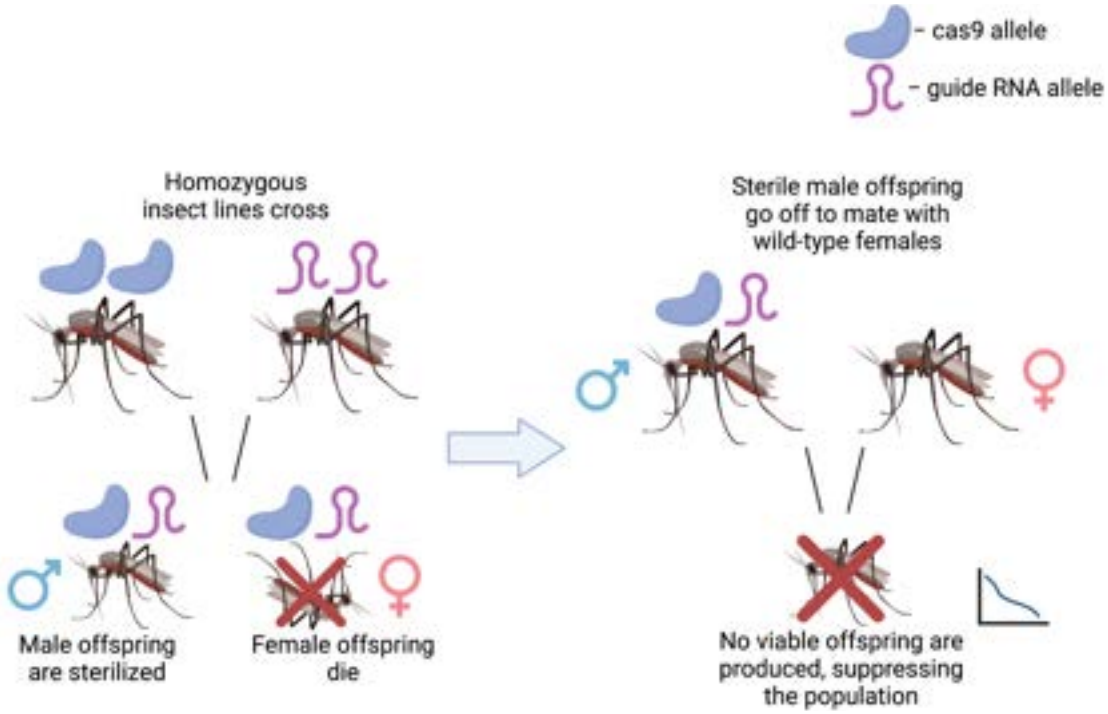

Figure 9: Process of reducing reproduction in populations by crossing homozygous insect lines, killing female offspring, and sterilizing male offspring. Releasing the sterilized males suppresses populations as no viable offspring are produced.

Although the traditionally used sterile insect technique has proved to be very sustainable, it uses radiation for sterilization which can cause chromosomal damage, making insects less fit ("Combating Mosquito-Borne Diseases with CRISPR"). CRISPR is a more effective precision-guided sterile insect technique (pgSIT) and does not affect the animals' chromosomes, which results in longer viability in the wild and a higher rate of population suppression through reduced reproductive rates ("Combating Mosquito-Borne Diseases with CRISPR").

Limitations/Concerns

The successful intervention and prevention of mosquito-borne diseases have been the subject of significant research and control efforts. However, despite substantial progress and

technological advancements, several restrictions persist in the field. Some typical concerns include limitations on time, cost, resources, ecological and ethical issues, and societal ignorance regarding the strategies of prevention. Certain high-risk areas require expedited solutions due to a progressively escalating number of cases, such as the dengue outbreak in Singapore (Cheema et al.). This is challenging, as strategies that target and suppress mosquito populations normally require at least a year to produce effective results (Hammond et al.). Some developing methods, such as utilizing Wolbachia-laced mosquitoes, could potentially lower the amount of time needed, as it is not only heritable but self-spreading (Kumar et al.; "Combating Mosquito-Borne Diseases with Bacteria"; "Bacteria-Laced Mosquitoes Limit Spread of Dengue"; "Dengue Cases Drop After Bacteria-Infected Mosquitoes Released"; "Dengue-Resistant Mosquitoes"). In addition, several remote areas do not have access to the resources they desperately need due to a number of factors - the main one being cost (Snehalatha et al.). Although practical, the technology used to execute next-generation solutions is expensive, and not easily accessible to low-income communities - most of which may lack a deep understanding of mosquito-borne diseases (Snehalatha et al.). Organizations such as the CDC provide global health funding to overseas countries to achieve the maximum public health impact (CDC Global Health Equity | Global Health | CDC). Another ecological concern is that genetic altering might lead to reduced fitness in mosquitoes and an inability to reproduce, making their ability to adapt to their original environment difficult (Kumar et al.; "Combating Mosquito-Borne Diseases with CRISPR"; Chen et al.). New strategies are emerging to mitigate this problem, such as using CRISPR to combat these ecological issues ("Combating Mosquito-Borne Diseases with CRISPR"; Chen et al.; Macias et al.; Li et al.). Moreover, it is imperative to provide education to residents living in high-risk areas about safeguarding themselves (Snehalatha et al.). Simple measures such as utilizing affordable insect repellents and mosquito trappers can serve as an added defense (Kumar et al.). Understanding the gravity of this matter is crucial for ensuring the well-being and safety of communities (Snehalatha et al.). Acknowledging and addressing these limitations will pave the way for achieving more comprehensive and sustainable solutions in the future.

Conclusion

The prevention of mosquito-borne diseases remains a global obstacle, given the social consequences brought onto public health. After assessing some increasingly effective heritable control strategies, including the current sterile insect technique (SIT), deactivating mosquito sperm, converting mosquito sex, Wolbachia bacteria-laced mosquitoes, and targeting disease carriers using CRISPR, the conclusion can be formed that different methods may be suitable for different areas. Based on the spread of diseases, areas may not require certain methods. For example, bacteria-laced mosquitoes that have the potential to reduce dengue transmission may not be used in areas where dengue is not as widespread, such as countries in the northern latitudes (Figure 1) ("Dengue Areas of Risk Around the World | CDC"). In some places, integration of methods could be used as well, based on the demographics and needs of that specific area (Table 2). A method of comparison to assess the needs and resources for each

unique situation, as well as what each method can offer, will maximize the likelihood of achieving favorable results (Table 2). For example, with no available vaccines to prevent the Zika virus spread primarily by Aedes mosquitoes, along with the number of cases reported in Brazil, converting mosquito sex to suppress the mosquito populations and using CRISPR to target the disease vectors could be a logical course of action (The Zika Outbreak of the 21st Century - PMC). Overall, the challenges posed by mosquitoes can be addressed on a broader scale using capable methods based on the specific characteristics and circumstances in different regions (Table 2). With the progressive evolution of research and technology, optimistic possibilities arise, envisioning the potential for complete eradication of the ongoing issue at hand.

Table 2: Comparison of all methods across various aspects. The first three columns show the three genera of mosquitoes, and an "X" indicates whether the technique has been proven to work in that type.

	Aedes	Culex	Anopheles	Population Suppression	Reduced Disease Transmission	Heritable	Affects Multiple Generations	Affordable	Human/ Environment Toxicity
Ineffective Solutions	X	X	X					X	X
Current Sterile Insect Technique (SIT)	X	X	X	X			X		
Deactivating Mosquito Sperm		X		X			X		
Converting Mosquito Sex	X			X		X	X		
Wolbachia Bacteria-Laced Mosquitoes	X			X	X	X	X		
Targeting Disease Carriers Using CRISPR	X			X	X	X	X		

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Author

Aradhana Sekar is a junior at Monta Vista High School in Cupertino, California. She is interested in studying biology and genetics and hopes to pursue a career in these fields. She also enjoys dancing and baking. She hopes to deepen and expand her knowledge of biological concepts in the future.

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Determinism vs. Probability: An Argument Between Physics and Philosophy by Laasya Daasari

Abstract

From Greek philosophers all the way to present day physicists, the "nature of the universe" debate has morphed from a philosophical discussion to a scientific one, highlighting the clear differences between quantum and classical mechanics. The recent developments of quantum mechanics have expanded our philosophical understanding of how the universe works. However, aspects of quantum physics itself, such as the collapsing of a wave function or what qualifies as a measurement are still being questioned due to our incomplete understanding of them, leading physicists to theorize quantum interpretations that predict what may be going on behind the scenes. Bell's theorem helps answer these uncertainties in quantum mechanics by ruling out local hidden variable theories, which in turn definitively shows that the universe cannot be governed by classical mechanics, because classical mechanics is a local hidden variable theory. By recognizing the universe behaves quantum mechanically, this paper concludes that the answer to this debate leans towards being probabilistic rather than deterministic. This conclusion is derived from the conflicting concepts of locality versus quantum mechanics and is supported by most quantum interpretations. Quantum mechanics does not allow for a local description of the universe. Overall, clearly understanding the processes and rules followed at the quantum level will lead to a better awareness of how our universe as a whole truly functions, especially on a quantum scale.

Keywords

Quantum physics, Philosophy, Determinism, Probability, Entanglement, Bell's theorem, Hidden variable theories, Locality, Quantum Interpretations

Introduction – Why is there an argument to be made?

Determinism is the philosophical idea that all events in the universe, from the tiniest atomic collision to decisions in our everyday lives, are sequential. They happen because other previous events caused them to happen. The key argument determinism makes is that these events were predetermined since the beginning of the universe (1). To the common person, determinism can be defined as "fate." However, one might doubt whether everything can be fixed from the start of our reality. The opposing philosophy is that every probability and small chance constantly changes the outcome of the future. With probabilities, there is a chance that something or some future event could play out differently. Considering these two different philosophies, an important question to ask oneself is, "Through what scientific means can we solve this debate?" Science can be helpful to provide knowledge from numerous experiments to apply a materialistic view to philosophical discussions such as this debate.

In the 20th century, scientists took sides in this discussion through the means of interpreting quantum physics (2). Albert Einstein, for example, believed in a strictly

deterministic world with an objective reality. He famously said, “God does not play dice with the universe” to express his thought that chances do not regulate the universe because they practically violate the apparent nature of classical mechanics (3). Classical mechanics presents a deterministic view of physics because events that happen on a classical scale are always perceived to be sequential (4). On the other hand, Niels Bohr, a distinguished physicist, argued that when it comes to quantum physics, there is no objective reality simply because the state of something is unknown until measured. His belief of uncertainty presented a challenge to the nature of classical mechanics, causing a distinction between the two regarding which philosophy can be applied to physics as a whole. To resolve this disagreement, Irish physicist John Stewart Bell designed a testable experiment known as Bell’s Theorem, in order to indirectly disprove one of these two differing views through analyzing quantum mechanics.
Bell’s Theorem yields the scientific insight on which this paper settles whether the nature of the universe lies in determinism or probabilities.

Bell’s Theorem

Bell’s Theorem was derived in 1964 by physicist John Stewart Bell in response to a claim made by Albert Einstein that quantum physics is an incomplete theory due to its uncertainties (5). A great example of this uncertainty in quantum physics is the Heisenberg Uncertainty Principle which states that the more precise measurement one can make about a particle's position, the information able to be obtained about the particle's momentum becomes continually more indistinct (6). This principle is extensively researched throughout the physics community and proven to show a definite uncertainty on the quantum scale.

Einstein, along with Boris Podolsky and Nathan Rosen, published a paper that contains a concept known as the EPR paradox that emphasized the uncertainties in quantum mechanical processes and their supposed invalidity (7). They proposed solutions known as “local hidden variable theories.”

Local hidden variables are defined as unmeasurable, internal characteristic(s) of particles that affect the state of a particle, meaning that any observation made of a particle containing local hidden variables would appear random, but are actually determined because we cannot identify them. In the case that it is possible to measure a local hidden variable, it would also be possible to predict an outcome of an observation, making the universe deterministic by ruling out the notion of probability. In that sense, Einstein attempted to disassociate quantum mechanics with uncertainty. Local hidden variable theories are deterministic in that they rely on a sense of locality, meaning that local factors to the environment of the particles cause said particles to behave a certain way (8). Therefore, they expand upon the fact that events are sequential, or dependent on previous variables.

However, Bell’s theorem ultimately disproved local hidden variables because they significantly violate Bell's inequalities. These mathematical inequalities set limits on obtainable values when performing an experiment to prove hidden variables. However, experiments to

prove local hidden variables have continuously violated these inequalities, proving time and time again that hidden variables do not exist (9).

The experiment begins with two entangled particles. Entanglement is a special property of quantum physics where two particles are dependent on one another in a way where the state of one particle will affect the state of the other. This quality is responsible for a lot of the questions and quirks associated with quantum physics (10).

In this experiment, each particle contains an internal characteristic known as "spin", or the intrinsic angular momentum of a particle. This property of spin can have two conditions along a given axis: "up" or "down." Due to the entanglement of the particles, they will yield opposite states once measured, meaning that if one particle is hypothetically measured as spin "down", then the other particle's state must instantly be spin "up" (11).

Now consider what occurs when the particles are separated by a large distance in space (10). The two particles can now be considered nonlocal. Nonlocality is the idea that a factor affecting an object is at a considerable, physical distance from the object (12). This is counterintuitive to us as human beings, as we relate the "cause" and "effect" of an event to be two factors that are local to each other. A hand pushing a ball off of a table is a "cause and effect" scenario where the hand and the ball are local. However, if the hand is on a different planet, it is hard to envision it still pushing the ball off the table.

Two different scientists assigned to each of the particles may make a measurement of the spin along certain axes of the particles and conclude that after measuring the state of one particle, the other will compulsorily be the opposite. For those interested in a more rigorous description of Bell's theorem, see the explanation in Griffiths (13). Therefore the experiment can conclude that the entangled particles will still show the same results after removing locality from the two particle system.

Arguably, the most significant takeaway from Bell's Theorem is the distinction established between "local vs. quantum mechanical." Since classical mechanics is a local hidden variable theory, therefore violating Bell's inequalities, Bell's experiment shows that the world is not classical, but rather it is quantum (14). Bell's experiment does this by proving a stronger statistical correlation between entangled particles than what local hidden variables can allow for. Although Bell did not know the implications of his theorem, many quantum mechanical experiments done over time have been able to better predict outcomes of particles than any local hidden variable theory. From these experiments, we can conclude that the results are incompatible with local hidden variable theorems and the world must behave quantum mechanically.

With that being said, what is the significance of the world being quantum mechanical? With the previous information one can infer that if the universe abides by the rules of quantum mechanics, then the nature of the universe should also be defined accordingly. It has already been established that quantum mechanics, to a large degree, contains uncertainty. However, it is possible to further analyze both quantum mechanics and local hidden variables to relate philosophies to each one. Then, the answer to this debate truly becomes clear.

Quantum Interpretations

Quantum interpretations are theories made to elucidate the aspects of quantum mechanics that are not completely defined to scientists. They are significant in identifying gaps of information in order to further our development of scientific thought relating to variables that affect quantum mechanics (15). It's important to note that a dilemma often arises in quantum mechanics when observing a particle's state. This problem points out the concept that a measurement is unable to have an absolute definition when shaping a particle's state. In simple terms, physicists have not yet found a way to answer the question "What exactly is a measurement?" (16). This notion is the main reason that physicists over a long period of time theorize these possible interpretations that could occur when taking a measurement.To analyze Bell's theorem, we can take a look at two different quantum interpretations: The Copenhagen interpretation and Local Hidden Variable theories.

The first theory is known as the Copenhagen interpretation. The Copenhagen interpretation is the most widely supported quantum interpretation used to describe what happens to a particle when it is measured. It claims that, prior to the action of measurement, a particle lies in multiple states at a single moment (17). This state is known as a quantum superposition. However, when a measurement is taken of the particle, some unknown aspect of the measurement causes the particle's superposition to collapse into one of its many probable states. This collapsing leads an observer to question whether the particle will settle into one state or another. This is the point of the interpretation where the concept of probability could apply. The particle itself is uncertain in the sense that the likeliness of one state occurring over another is merely a probability.

During the time before the particles in Bell's experiment are measured, the Copenhagen interpretation evaluates that the particles are in a quantum superposition. The entangled particles share an inseparable wave function until the moment that one of the particles is measured. This signifies that before the measurements are made, the state of the entangled particles are uncertain and, therefore, are probabilistic because the possible outcomes of the particle can be one of many. These outcomes result in different conceived possibilities of how a sequence of events could play out based on the state the particle settles in, of which one state may be more likely than the other due to specific characteristics of the particle or measurement.

One thing the Copenhagen interpretation does not mention however is that it is possible the available outcomes we predict may only be the outcomes that we are able to foresee with our present knowledge (18). Any possible outcomes that we have not yet recognized to exist may not exist to us as humans in the present moment, therefore leading to even more uncertainty associated with quantum mechanics. This uncertainty itself is what Einstein rejected against his own belief of an objective reality.

The next attempt at explaining a particle's state after a measurement does take a more deterministic approach. Hidden variable theories, as previously mentioned, suggest that particles have an internal trigger from within the particle that causes them to present a single state when

measured. These theories conserve the concept of locality, or the idea that factors of the environment surrounding an object or particle directly affect the state of the object or particle (19). Locality is commonly found in the classical world around us, such as when a ball is pushed off a table. It is accurate to assume the trigger pushing the ball off the table causes it to fall or affects the ball in some way. Therefore, the trigger is "local" to the ball. Locality is objectively deterministic as it directly states that one event causes another event to occur in which the latter event was predetermined when the trigger provoked it to unfold. In that sense, classical mechanics can informally be described as "one big local hidden variable theory." An important aspect of this theory to mention, once again, is that local hidden variables are variables unknown to us as humans. This means that if they existed, and we knew a way to calculate them, they could be hypothetically plugged into a deterministic equation to predict future events (20).

Hidden variable theories often suggest that when one of Bell's particles is measured, an internal, unknown, and local characteristic of the particle is what causes it to either result in "spin up" or "spin down." This concept is deterministic as it assumes a small trigger in a particle automatically predicts the particle's future, settled state. However, this deterministic explanation proposed by Einstein and others ultimately ends up disproven. Additionally, many other hidden variable experiments have all commonly violated Bell's inequalities, meaning that the states of the particles could not be deterministic (21).

Conclusion

Bell's inequalities allow for scientists to test whether the world is quantum mechanical or local. After many tests invalidating local hidden variable theories, it is reasonable to assume that the world cannot abide by locality on any scale, but rather only by quantum mechanics. Because quantum mechanics fundamentally includes uncertainty in its description of the universe, the universe therefore cannot be deterministic.

Furthermore, if the universe ultimately relies on quantum mechanics, its true nature lies in probabilities as seen through the evidence supported by quantum interpretations.

Therefore, the world is simply probabilistic.

On a larger scale, this means that every decision and event that occurs in our lives changes our future from the tiniest, quantum particles to our daily "classical" lives. This realization that probabilities rule our universe is significant to further developing our understanding of quantum physics. Even throughout the evolution of quantum mechanics, we've learned that our understanding of the universe cannot be replaced with classical mechanics. So while this realization may seem like a minor detail, the application of it can lead to new quantum theories and lab experiments along with more thought-provoking problems to incentivize more brilliant minds to evolve the field of quantum physics. Additionally, through scientific advancement, there is growing potential to provide solutions to other unsolved philosophical debates.

In closing, the progression of physics is a never-ending road in which so many travel with the aspiration to learn and discover something new. With this ambition along with principles of philosophy, this path will continue to shape and define science as a whole throughout time.

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The Encoding of Emotions in Memories in Context with Post-Traumatic Stress Disorder: A Literature Review by Rishi Dasari

Abstract

Post Traumatic Stress Disorder (PTSD) affects roughly 3.5% of the adults in the United States every year. Likewise, it is estimated that 1 in 11 adults will suffer from PTSD during their lifetime. PTSD is a psychiatric disorder that develops in individuals following traumatic experiences. This condition has the ability to impact physical, mental, and emotional wellbeing and can induce an array of symptoms including intrusive thoughts, involuntary memories or flashbacks, nightmares, increased negative emotions, and unsafe behavior, which can be debilitating (Taylor-Desir, 2022). In this literature review surveying recent findings on emotional memories and PTSD, I aimed to better understand how emotion and memories and the neural structures underlying these cognitive abilities play a role in this complex mental health condition. It was found that all three subcomponents of episodic memory - encoding, storage, and retrieval - have been implicated in PTSD symptoms. Furthermore, it was found that specific neural regions that are involved in memory and emotion, including the hippocampus and amygdala, undergo physiological and functional changes following a traumatic event, resulting in the symptoms characteristic of PTSD. Understanding PTSD starts with understanding basic principles of memory processing. More research in this topic will allow clinicians and mental health care providers to develop individualized treatment programs that are more effective.

Introduction

Post Traumatic Stress Disorder (PTSD) is a psychiatric condition that occurs in individuals who have experienced, witnessed, or heard of a traumatic event. This condition affects their physical, mental, and emotional wellbeing and can induce symptoms such as intrusive thoughts or unwanted images or ideas that come to mind; involuntary memories or flashbacks in which vivid sensory memories are recalled inappropriately; nightmares; increased negative emotions, especially fear; unsafe behavior potentially leading to self-harm; and more (Taylor-Desir, 2022). PTSD affects roughly 3.5% of the adults in the United States every year and it is estimated that 1 in 11 adults will suffer from PTSD during their lifetime. Additionally, PTSD affects women and certain ethnic minorities disproportionately (Taylor-Desir, 2022).

Given that many symptoms of PTSD relate to memories of the traumatic event, it is no surprise that memory plays a critical role in PTSD. Memory is an umbrella term for a number of distinct abilities that we possess as cognizant beings. The function of memory is mainly centered in the region of the brain known as the hippocampus (Carr et al., 2011). Here, there are multiple types of memory which are stored differently. The first of which is episodic memory or the memory of experiences/episodes in one's life. Another type of memory is working memory which is a system that holds information temporarily in the mind. The third type of memory is semantic memory which maintains facts or general knowledge. Additional memory types include short-term memory, long-term memory, among others (Types of Memory, 2016). Here, I will

focus specifically on how episodic memory is involved in PTSD. Episodic memory can be further broken down into three subprocesses: encoding, storage (also referred to as consolidation), and retrieval. Encoding refers to the initial act of internalizing an experience in the brain, storage refers to the retention period of the memory over time, and retrieval refers to the process of recalling a memory after successful encoding and storage (Noba, 2023). Each of these subprocesses will be examined in the context of PTSD individually. This literature review aims to highlight the relationship between memories and emotions, their underlying neural structures, and the connection with PTSD. Further, how these findings relate to the symptoms of PTSD to better understand the effects of the neural changes during the memory encoding process will be discussed. It was hypothesized that emotion changes the way in which memory is processed by potentially altering the brain's composition which will in turn result in highly emotional events, such as traumatic ones, inducing the strong symptoms found in PTSD (i.e., nightmares and flashbacks).

Methods

For this literature review, Google Scholar was used to search for and identify research papers assessing PTSD and memory and emotion. Search terms used to find papers included "neural changes during PTSD," "hippocampal memory retrieval," "PTSD symptoms," and "impacts of emotion on memory." Search results were limited to papers published in the last 25 years for the most accurate and up-to-date information. Additionally, YouTube was used to identify informative videos created by credible therapists and academic sources working on better understanding PTSD and neurophysiology. Subject terms such as "basic neurobiology" and "neurophysiological change post-trauma" were used to identify relevant videos. Finally, Google was used to find articles with general information regarding PTSD frequency and basic memory principles. Search terms including "PTSD in the United States" and "different types of memory" were used.

Results

Five research papers, four articles, and one video relevant to the topics of PTSD and emotional memories were identified and analyzed here. Two of the research papers assessed the effects of stress on memory, one examined flashbacks, a symptom of PTSD, one described the effects of insomnia and nightmares on PTSD severity, and the last contained information on memory consolidation and retrieval in the hippocampus.

Discussion

Memory

Knowledge of memory function is highly important to understanding PTSD. As mentioned, episodic memory has three subcomponents, all of which have been implicated in PTSD symptoms. The first subcomponent is encoding, which refers to the first instance of

perceiving certain information (Noba, 2023). Given that in a typical environment there are far too many pieces of information to successfully encode, our brains have to choose specific articles to remember. This leads to the first principle of encoding: selectivity (Noba, 2023). As humans, we pay attention to certain events happening in the world around us while we ignore others, which becomes important when taking into consideration the kinds of events that have a greater chance of being encoded. Even though only specific events are encoded, the second important feature of encoding is that it is constant; we constantly try to encode information around us (Noba, 2023). Ordinarily, this presents no issue as our lives are routine and we understand our surroundings, but when something seems out-of-place, it becomes memorable. The distinctiveness of an event is important as it increases the chances of the particular event eventually being retrieved (Noba, 2023). Furthermore, vivid memories are often associated with powerful emotions.

Vivid memories are important in the context of PTSD as most traumatic events are able to leave a stronger imprint in our minds (Noba, 2023). The vividness of a memory can also lead to the experience being more frequently retrieved, even involuntarily. As individuals experience these involuntary symptoms, the frightening nature of the memory can result in anxiety and stress. It is important to note that the vividness of a memory does not imply accuracy. The process of encoding also involves what is known as "recoding," which simply means converting information that has been encoded in a way that is comprehensible (Noba, 2023). While the purpose of recoding is to help us remember, it can also introduce errors by adding new information that was not present in the initial experience (Noba, 2023). This can also lead to PTSD symptoms such as involuntary memories and nightmares because the inaccurate nature of recoding introduces new elements that enhance the threat. The individual may not even be aware that these elements of the memory never existed.

The second phase of memory processing is storage, also referred to as consolidation. Psychologists say that every event we experience creates a memory trace or engram. In order for the brain to store a memory, it essentially creates a memory trace and alters its physical composition to do so (Noba, 2023). It is important to note that these traces are not perfectly accurate recordings of the occurrence, rather it can be thought of as a device that our brain uses to help reconstruct the event, making memory a creation of what we believe happened and not necessarily what actually happened (Noba, 2023). This is highly relevant in context of PTSD because an individual may unintentionally reconstruct a memory that is exaggerated and more frightening than the original experience was due to flawed recoding.

The third and final subprocess of memory is retrieval. Retrieval is perhaps the most important subprocess as there is no purpose in memory storage if we cannot recall them. While we encode and store a vast amount of information, only a small portion of that information is ever retrieved (Noba, 2023). Environmental cues play a large role in triggering certain memories. This led researchers to develop the encoding specificity principle which states that humans encode information in specific manners (Noba, 2023). For instance, if an individual once had an experience where an elevator malfunctioned while they were using it, the sight of elevator doors

(cue) may trigger the memory of being stuck in the elevator for three hours (experience). This relates to PTSD because an environmental trigger associated with a traumatic memory can cause PTSD symptoms such as flashbacks or involuntary memories (Brewin, 2015).

Furthermore, stress levels can also affect memory retrieval in PTSD patients. A series of studies examined the effects of increased cortisol release in individuals with mental health conditions. It was found that the individuals with PTSD and increased cortisol displayed enhanced memory retrieval, indicating an increased sensitivity to cortisol as well as altered function of episodic memory (Wolf, 2017).

Physiological Alterations in Brain Structures

Several areas of the brain are implicated in PTSD. The most notable are the amygdala, hippocampus, and prefrontal cortex. The amygdala is the emotional center of the brain - it is the site of all feelings (Roozendaal et al., 2009). Additionally, it is the part of the brain that perceives threats, and triggers the fight-or-flight response to threatening situations (Therapy in a Nutshell, 2022). After a traumatic event, the amygdala becomes much more active, meaning it will become more likely to trigger the fight-or-flight response. This hyperactivity can result in perceiving a harmless situation as threatening and causing the person to be more anxious even when at rest (Therapy in a Nutshell, 2022). An individual with PTSD may experience this overreaction. For example, a person who had a terrifying experience in an elevator may associate that experience with anything remotely related to an elevator – a metal door in an office building may remind the individual of the doors of the elevator they were trapped in; a microwave beeping when it finishes warming food can cue the memory of the elevator beeping. Harmless objects in the individual's environment can stimulate the fear response, resulting in the person being constantly stressed (Therapy in a Nutshell, 2022). This relates to the environmental cues triggering specific memories through the encoding specificity principle. The increased sensitivity of the amygdala can lead to a wider variety of objects in the environment to trigger the memory of the original traumatic event. This type of memory is a flashback and is a symptom of PTSD (Brewin, 2015).

The hippocampus is the memory center of the brain and is highly important for learning (Carr et al., 2011). All of the aforementioned subprocesses of creating memory largely take place in the hippocampus. After a traumatic event, the increased stress levels and anxiety cause the hippocampal region to be less effective at processing specific emotions (Therapy in a Nutshell, 2022). In fact, neuro-imaging findings reveal that the hippocampus physically loses enough mass to impair function (Therapy in a Nutshell, 2022). Furthermore, the weakened hippocampus causes the brain to be less effective at differentiating between past experiences and present situations (Therapy in a Nutshell, 2022). This deficit is the reason flashbacks occur in individuals with PTSD. Flashbacks are essentially memories that feel very real due to the visual component, often triggering the amygdala to activate the fight-flight-freeze response even when there is no legitimate threat (Therapy in a Nutshell, 2022). Over time, the connection between the

hippocampus and the amygdala grows stronger and maintains the fear response even if the individual no longer remembers the original event (Therapy in a Nutshell, 2022).

Additionally, the prefrontal cortex is the neural region responsible for rational thought, critical thinking, and organization (Therapy in a Nutshell, 2022). Following a traumatic event, the prefrontal cortex can become stuck in the fight-flight-freeze response and this results in decreased activity in this region (Therapy in a Nutshell, 2022). Additionally, the prefrontal cortex, similar to the hippocampus, shrinks by an amount just large enough to have an effect on its function (Therapy in a Nutshell, 2022). When rational thought is impaired, the signal of a threatening situation sent by the amygdala overrides the prefrontal cortex's ability to logically perceive the situation as safe. This is why it becomes so difficult for an individual with PTSD to remind themself that the danger is not real when they suffer a flashback, involuntary memory, nightmare, or other symptom (Therapy in a Nutshell, 2022).

Finally, the broader nervous system is flooded with stress hormones and neurotransmitters, putting the body in a state of hyperarousal post-trauma. An individual in this state will feel constantly anxious and stressed to the point of exhaustion when they will shut down. This puts incredible strain on the body and can cause a weakened immune system which can lead to someone being in poorer overall health and more susceptible to diseases (Therapy in a Nutshell, 2022).

Flashbacks, Insomnia, and Nightmares

When PTSD was first characterized as a serious psychological disorder, dissociative flashbacks were found to be one of the hallmark symptoms (Brewin, 2015). Characteristics of flashbacks include the involuntary nature with which they occur, the vivid sensory details, and the overwhelming feeling of the event occurring in the present (Brewin, 2015). These attributes occur due to the neurophysiological changes in the brain post-trauma detailed in the previous section. To investigate this further, a research study asked multiple PTSD patients to write down the details of their trauma. Then, the patients were interrupted while writing the narrative to perform certain visuospatial tasks. It was found that the subjects who were writing sections that pertained to flashbacks performed worse at these tasks than subjects who were writing ordinary memory sections, implying impaired cognition in this hyperaroused state (Hellawell and Brewin, 2002). Similar studies performed later found that patients had an increased heart rate while detailing flashbacks in their writing (Brewin, 2015). Additionally, the flashback sections of the narratives contained more sensory phrases and PTSD-associated emotions such as fear and helplessness than other sections (Hellawell and Brewin, 2004). These results highlight the increased anxiety and stress levels associated with flashbacks. Current research indicates that flashbacks occur as a result of encoding memories under acute stress. Flashbacks depend on a stress-related excess of activity in the dorsal visual stream, which is a neural region specialized for visualizing the environment that can be used to direct immediate motor responses to threat (Brewin, 2015). Neuroimaging studies show that flashbacks are associated with higher activity in the amygdala, but also in additional neural regions, including the motor areas and insula. This

indicates that flashbacks are produced by certain patterns of neural activity that separate them from ordinary episodic memories (Brewin, 2015).

Nightmares and insomnia are two additional distinctive symptoms of PTSD. A study analyzed the presence of nightmares and insomnia in a cohort of predominantly male veterans with PTSD. They compared the presence of these symptoms to the severity of PTSD and depression in the participants. It was found that the veterans with insomnia at baseline had significantly higher levels of both PTSD and depression (Pigeon et al., 2013). Another data set examined nightmares as the independent variable instead of insomnia. Similar levels of PTSD severity were found (Pigeon et al., 2013). Sleep disturbance is an incredibly important symptom of PTSD and such disturbances have been found to be related to subsequent mental health symptoms. Sleep difficulties are related to both physical and emotional issues, and poor sleep can also exacerbate existing mental health problems (Torres, 2020). Additionally, individuals with insomnia tend to have an inferior capacity to manage their other symptoms compared to individuals with PTSD without sleep disturbance (Pigeon et al., 2013). This emphasizes sleep quality as one of the crucial symptoms to track and maintain in PTSD patients. Sleep interventions and pharmaceuticals, such as prazosin, were found to be helpful in reducing the symptoms, however more research needs to be done to fully resolve these disturbances (Pigeon et al., 2013).

Future Directions

Future work should focus on understanding the underlying mechanisms of flashbacks and dreams. Additionally, researchers should examine different types of therapies, treatments, or medications that more effectively mitigate the various symptoms of PTSD in future work. One important precaution to take in further PTSD studies is ensuring that the data is measured through clinical assessments and interviews rather than just self-report measures. Use of these kinds of assessments will mitigate the risk of underreporting of symptoms caused by patients downplaying their symptoms due to the stigma surrounding mental health and PTSD.

Limitations

It is important to consider the findings presented here in the context of the limitations of this paper. The primary limitation of this literature review is that it is not a systematic review. Here, I focus on recent and relevant information in understanding emotional memories and PTSD to present the most up-to-date work. Therefore, there may be additional research papers examining this topic which are not captured in this literature review.

Conclusion

Understanding PTSD begins with understanding how the human brain processes memory and emotions. Memory is an extremely complex process, and each subprocess of memory has been implicated in PTSD. These connections are also related to changes in the amygdala, hippocampus, and prefrontal cortex. Additionally, there are several symptoms that are

characteristic of PTSD that include nightmares, insomnia, and flashbacks. Better knowledge of emotional memories and PTSD this topic will inform researchers of the various neural changes that occur during and after severe trauma. In turn, this information will be able to aid physicians and mental health clinicians in developing better treatment and prevention programs for their patients suffering from PTSD.

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A Machine Learning Approach to Predict the Occurrence of Forest Fires with Meteorological Parameters by Yashnil Mohanty

Abstract

Forest fires have emerged as a considerable challenge in the United States, posing substantial societal, economic, and environmental risks. As a result, the early and accurate prediction of these fires is imperative for management efforts. In this study, we used two Kaggle datasets: the "Algerian Forest Fires Dataset" with fire readings from 2012 and the "Forest Fires Data Set" with readings from 2007. However, because the second data set was originally intended for a regression task, providing approximate area values representing the predicted burned area of the forest fire, we phased the data set out while developing our final model. Ultimately, we used the Algerian Forest Fires Dataset, containing 13 attributes and 244 instances of forest fires in two regions of Algeria. To streamline the analysis, we reduced the number of features to 5, namely, month, temperature, humidity, wind, and rain. Moreover, we developed a Random Forest Classifier model to predict the occurrence of a forest fire, using the data set for training and testing. Performance was compared against Decision Tree, Logistic Regression, and Artificial Neural Network models, using cross-validation. The experiment showed a slight superiority to the Random Forest Classifier approach, achieving an accuracy score of 86.486% and an F1 score of 88.889%. Our approach provides a decimal value representing the probability for fire likelihood. Overarchingly, this research contributes to the advancement of forest fire prediction technologies by leveraging meteorological data.

Introduction

Forest fires have become an imminent threat worldwide. Hotter and drier weather caused by climate change and poor land management create conditions favorable for high-intensity forest fires [1]. In the United States, there has been an annual average of 70,025 wildfires burning an annual average of 7 million acres since 2000 [2]. In recent years, this number has skyrocketed to unprecedented heights as the effects of climate change continue to persist. An increase in forest fires directly leads to an increase in global warming, in addition to many additional risks posed by forest fires, including threats to biodiversity, infrastructure, and health [3]. The ability to be able to accurately prevent the occurrence of a forest fire by taking real-time readings from weather stations could assist in helping mitigate this problem. By simply utilizing real-time meteorological readings from weather stations, this classifier model could ultimately lead to park officials taking early action for crowd control in case an area is at imminent risk of a fire. This could ultimately help assist in the early prevention of forest fires by determining whether the weather conditions are conducive to the occurrence of a fire. We decided to test our data on several different classifiers and run cross-validation on the results to ultimately determine a superior method for this approach.

Literature Review

` In this section, we review current approaches that we have encountered in the literature.

In the past, meteorological data has been incorporated into numerical indices, which are used for prevention and management strategies. For example, the Fire Weather Index System, which we further on about in the next section, was developed in the 1970s with simple mathematical calculations using only readings from four meteorological observations: temperature, relative humidity, rain, and wind. The FWI System has become a common method to test the occurrences of forest fires around the world [4].

We created a Random Forest Classifier method that determines the probability of forest fire occurrences through the votes of individual decision trees. Our model was trained on the Algerian Forest Fire Dataset with 244 instances and 13 parameters. However, through pre-processing, we narrowed this down to only 4 parameters. To contextualize our work within the developing field and assist with the creation of a robust machine-learning model, we surveyed several different relevant pieces of literature.

In this literature review, the focus is on exploring the existing knowledge and advancements in machine learning about forest fire management. The review aims to analyze the evolution and current state of machine learning models employed in addressing the occurrences of forest fires.

Abdelhamid Zaidi

Abdelhamid Zaidi's research contributes to fire prediction using an Artificial Neural Network (ANN) architecture. Zaidi's study applies this ANN model to predict the occurrences of forest fires in Algeria. The Artificial Neural Network architecture consists of two hidden layers and his work focuses on the same target scope as us, the general prediction of forest fires. Zaidi utilizes the same dataset that we used, the Algerian Forest Fires Dataset, to train and test the ANN model for fire prediction. The dataset incorporates six variables as reduced by PCA. He achieves a 96.65% accuracy with his model. A key difference between our model and his is that he relied on the FWI Index Parameters, which we intentionally omitted due to the lack of readily available information on how to obtain the respective values. We additionally aimed to learn the relationship between standard meteorological data input and the likelihood of fire rather than using predefined weights, as provided by the FWI System. This makes our model more versatile since we can rely solely on weather parameters. Moreover, our model achieves this by using a Random Forest Classifier, which has a notably lower computational cost and time [5].

Mauro Castelli et. Al

Mauro Castelli’s research contributes to fire prediction using an experimental artificial intelligence system called geometric semantic genetic programming (GSGP). Castelli’s approach applies this system to predict the burned areas of forest fires, suggesting a more regressive approach and task. Castelli and his colleagues used the Forest Fires Dataset, which happened to be the exact dataset that we originally used and phased out. This dataset was created from 517 instances of fires in Montesinho National Park in Portugal between 2000 and

2003 and precisely includes 12 different parameters. GSGP works by improvising a Genetic Programming (GP) model. GP is an evolutionary algorithm that operates using evolving models by modifying old ones through genetic operators. GSGP then introduces further geometric semantic operators that consider the semantics or meaning of the programs in addition to their syntax. Mauro Castelli's work thus focuses on burned areas within fire prediction. He obtains a testing error of around 10-20 percent, though the exact number remains unspecified. Our model in comparison achieves a similar testing accuracy but serves a different purpose. Whereas Castelli's original work aims to predict the burned area of forest fires, we aim to predict the occurrence of one through solely meteorological data. This makes our work unique [6].

The Fire Weather Index System

Both of the datasets we used for this project incorporated the Fire Weather Index (FWI) System into their input readings (as attributes for the dataset). Based on a Canadian empirical model, FWI is one of the most widely used fire weather indices for measuring wildfire risk. The FWI System relies solely on weather readings that can be found in weather stations. It's recursively calculated using yesterday's data and current meteorological readings [4].

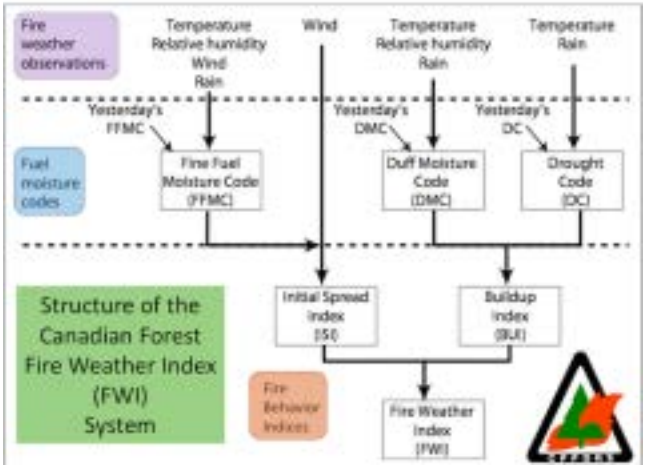

Figure 1. Structure of the Canadian Forest FWI System (NWCG 2023).

Summary of Approach

To proceed with the development of this model, we first extracted a dataset from Kaggle. Initially, we downloaded two datasets with the hopes of creating a merged dataset with 761 instances. However, as we realized later, this was a suboptimal approach as one of the datasets we were using was meant for a regression task instead and the data was not organized in a way suitable to our model. So eventually, we completely phased out that dataset and decided to only proceed with one of our datasets. At the earlier stages of our model, we preprocessed both datasets to create a merged dataset with multiple features. Initially, we did not phase out the use of the FWI parameters, but later, as we tested out different variations and combinations of the datasets, some inclusive and some exclusive of the FWI parameters, we decided to pursue the variation that is presented in this research paper. After we decided on a version of the dataset,

we ran PCA to optimize our training data and then used the train_test_split() function to test the data into training and testing data. We then ran the data through four different baseline models and selected the model with the best accuracy. We then tuned the hyperparameters for optimal cross-validation performance. To ultimately fulfill our goal of predicting the probability of a forest fire, We used the predict_proba() function to split the decision trees in the RFC model to give a resulting probability of the occurrence of a forest fire.

Data Analysis

Dataset

For this project, We used several different datasets. We downloaded two datasets on Kaggle, namely, Algerian Forest Fires Dataset and Forest Fires Data Set. We ultimately trained and tested the model on several variations of one or both of the datasets combined, to see which one would produce the most optimal and generalizable results.

Algerian Forest Fires Dataset

This dataset includes 244 total instances of forest fires in Algeria in the year 2012. There are 13 input features and 1 output attribute, which is the classification of fire or not fire. This dataset incorporates all six of the features noted above, in addition to all four necessary standard attributes found in weather stations: temperature (Celsius), humidity (%), wind (km/h), and rain (mm). This dataset also included the day of the month, the month of the year, and the year, which was a constant of 2012. The output was a class, namely fire or not fire.

No.	Attribute	Description
1	Day	Day of the Month
2	Month	Month of the Year (as a number)
3	Year	Year (2012)
4	Temperature	Temperature at noon (in Celsius)
5	Humidity	Relative Humidity (in %)
6	Wind	Wind Speed (in km/h)
7	Rain	Total day (in mm)

8	FFMC	Fine Fuel Moisture Code
9	DMC	Duff Moisture Code
10	DC	Drought Code
11	ISI	Initial Spread Index
12	BUI	Buildup Index
13	FWI	Fire Weather Index
14	**Target**	{fire: 1 | fire: 0}

Table 1. Attributes of the Algerian Forest Fire Dataset

Forest Fires Data Set

This dataset includes 517 total instances of fires in Montesinho National Park in Portugal. There are 12 input features, including FFMC, DMC, DC, and ISI, as well as temperature, humidity, wind, and rain. In addition to that, the dataset also includes the x and y coordinates, month, and day of the week as features. The output attribute is the burned area of the respective fire instance. This dataset was meant to be a regression problem, as the output attribute is a burned area given the meteorological parameters, rather than a binary class of fire/not fire. Note: The Forest Fires Dataset was modeled with ln(x+1) at the beginning since the distribution was so heavily skewed towards 0 (a logarithmic function can effectively compress extremely large data points). They eventually transformed the model's output back to its initial values by running it through the function e^x-1.

No.	**Attribute**	**Description**
1	X	X-axis spatial coordinate in Montesinho National Park
2	Y	Y-axis spatial coordinate in Montesinho National Park
3	Month	Month of the Year

		(‘jan’ to ‘dec’)
4	Day	Day of the Week (‘mon’ to ‘sun’)
5	FFMC	Fine Fuel Moisture Code
6	DMC	Duff Moisture Code
7	DC	Drought Code
8	ISI	Initial Spread Index
9	Temperature	Temperature (in Celsius)
10	Humidity	Relative Humidity (in %)
11	Wind	Wind Speed (in km/h)
12	Rain	Total day (in mm)
13	**Target**	Total burned area of the forest fire (in hectares)

Table 2. Attributes of the Forest Fires Data Set

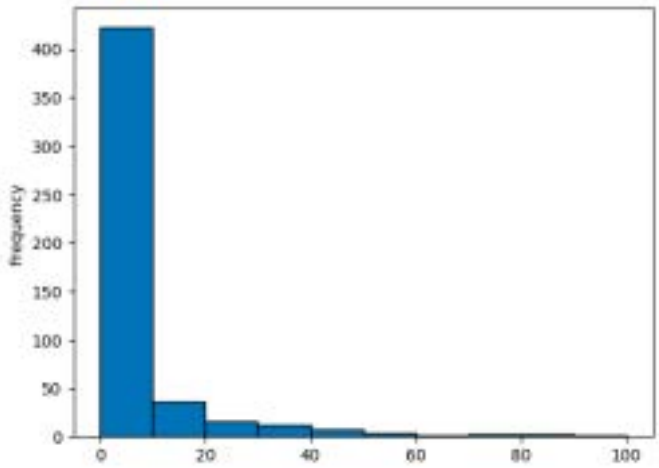

Figure 2. Frequency of Areas of Forest Fires in the Forest Fires Data Set

Inaccuracies and Notes

While testing the data through multiple variations of both datasets, the results of the Portuguese dataset seemed to always perform much poorer than the results of the Algerian Data Set. The cause of the inaccuracy in the Portuguese data set seems to most likely be 2 things: (1) According to the EPA, a wildfire is defined as a fire larger than 1000 acres in the Western United States and 500 acres in the Eastern United States [7]. Even if we use the 500-acre threshold, only 4 of the 517 instances in the Portuguese data set meet the sufficient criteria for a 500-acre (202

hectares) fire. The rest of the instances where a fire took place were simply not large enough to be considered a wildfire. (2) Of the instances, already, the majority of them are equal to 0. By changing the bounds for a fire to a max of even 10 hectares (~25 acres), which wouldn't be considered a wildfire by any metric, nearly 450 of the instances are classified as "not fire," suggesting the data is extremely skewed towards 0, as represented in Figure 2. The main hitch with turning a regression data set into a classification one is that the data points/instances aren't exactly the best for wildfire prediction as the dataset was intended to mostly calculate the spread of a fire rather than the occurrence of one. This is why we phased out this dataset completely, as the data points for the Algerian data set more accurately represent that of a forest fire.

Preprocessing

We ultimately decided to use the Algerian Forest Fires Dataset as the Forest Fires Dataset was more fitting for a regression problem. We omitted all the columns except temperature, humidity, wind, rain, and month. The reason for this is that we found little correlation between day and year with the occurrence of a fire. Furthermore, we intentionally omitted the FWI metrics because we were unable to find any significant information on how to calculate and obtain these metrics, meaning that for further use of this model, these would be largely insignificant. Therefore, we decided to only use the four main meteorological parameters and the month, as they would be easy to obtain and they were effective enough in training and testing this model.

The final data set we used had 5 features (columns) and 244 instances (rows). Figure 3 highlights the data distribution of each of our features.

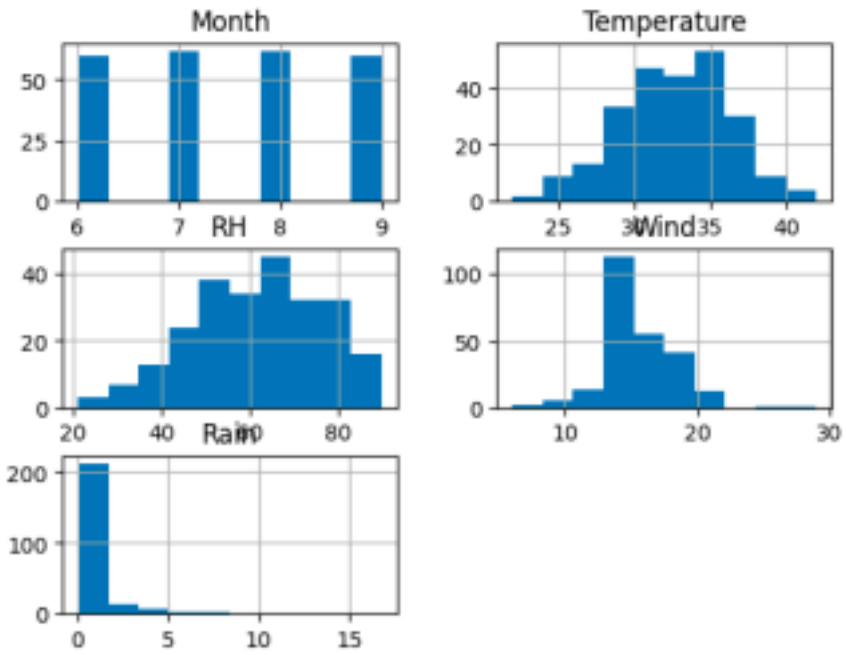

Figure 3. Histograms of Attributes

We used the train_test_split() function to break the data up into training and testing datasets. We used a 30% test size sample.

Correlations and Running PCA

Principal Component Analysis (PCA) is a widely used statistical technique in dimensionality reduction. It is commonly used to simplify datasets with a high number of features while retaining essential information and reducing redundancy in the data. Reducing the number of variables typically comes at the expense of accuracy, but PCA generally effectively trades very minimal accuracy with data simplicity. It is often useful to perform PCA before building a classification model, as PCA can reduce the number of explanatory variables, which in turn reduces the computational demand of a model [8].

On our omitted data, we ran a heat map to test the correlation between different features, shown by Figure 4.

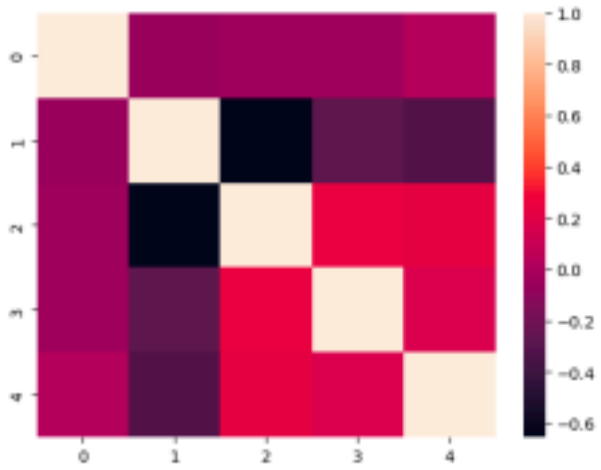

Figure 4. Correlation Between Attributes

We then ran the PCA algorithm with 99% variance with the scaled data, and the algorithm didn't reduce the data frame at all. In other words, the PCA algorithm found a high correlation and usefulness in all features that we used. As a result, we decided to train and test the model on the preprocessed data set without modifying it any further.

Models

Decision Trees

Decision Trees are a popular machine-learning model. They are used to make decisions by recursively splitting the dataset into subsets based on the most significant attributes. Decision Trees start with a root question, referred to as the root node, which represents the entire dataset. The tree is then successively built by splitting the dataset into smaller subsets. Each internal node represents a "test" on the attribute (for instance, whether a coin flip comes up as heads or tails). This decision then divides the data into two or more child nodes. Each split allows the data to arrive at a conclusion, denoted by the leaf node. When splitting the data at each node, a splitting criterion is used to determine the feature and split point that best separates the data into subsets. Various metrics, including Gini impurity, information gain, or mean square error, can be used to evaluate the quality of the split [9].

Random Forest Classifier

Random Forest (RF) is a commonly used machine learning algorithm, proposed by Leo Breiman in 2001. A Random Forest combines the output of multiple independent decision trees to reach a single result. Each tree has a partial vision of the problem due to random sampling:

- A random sampling on the observations with replacement (the rows of the dataset), known as tree bagging ◦ This involves constructing n decision trees by taking a random sample of the dataset (with replacement), then training each of the n decision trees independently, and taking the majority of these n predictions as a result
- A random sampling on the variables (the columns of the dataset), known as feature

sampling ◦ This process involves randomly sampling several features from the given dataset. By default, we randomly sample ⌈√p⌉variables in a dataset with p total features. For a set of randomly selected

variables, a decision tree is created after tree bagging, which reduces correlation among distinct decision trees, which could alter the results [10].

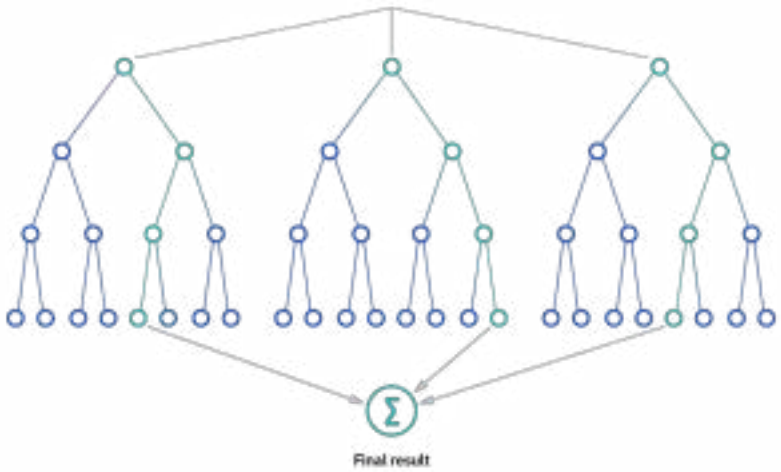

Figure 5. Random Forest Algorithm (IBM)

Logistic Regression

Logistic regression (or a logit model) is a classification model that estimates the probability of an event occurring based on a linear combination of independent variables (features). The dependent variable (output) is a probability bounded between 0 and 1. In a logistic regression, a logit transformation is applied to the odds - which is a ratio of

the probability of success and the probability of failure. This is commonly known as the log odds, represented by the following formulas:

$$\log\left(\frac{x}{1-x}\right) = \frac{1}{1+e^{-x}}$$

$$\ln\left(\frac{x}{1-x}\right) = b_0 + b_1x_1 + \ldots + b_kx_k$$

In this logistic regression equation, logit(pi) is the dependent variable and x is the independent variable. The beta parameter, or coefficient, in this model, is commonly estimated via maximum likelihood estimation. A logistic regression seeks to maximize this function to find the best parameters. Once the optimal coefficients are found, the conditional probabilities for each observation can be summed together to yield a final probability. For binary classification, this probability is typically rounded [11].

Multilayer Perceptron (Artificial Neural Network)

An Artificial Neural Network is an interconnected system of neurons, also known as

nodes, that process input to produce the desired output. Each of these neurons is connected by inputs, weights, and activation functions. ANNs are known for their learning capability, trained on known examples to then solve unknown problems. They learn through supervised or unsupervised learning: supervised involves known target values to minimize output errors, while unsupervised involves the network self-learning from data by detecting patterns or clustering similarities. A neural network typically comprises an input layer, hidden layers, and an output layer. Depending on the structure, ANNs are categorized as single-layer or multi-layer networks based on the presence of hidden layers [5].

Regarding some ANN parameters and hyperparameters:

- Weights: Links between neurons each carry a weight that holds input signal information. These weights often help calculate outputs. In a matrix with 'r' nodes and 'c' weights per node, denoted as W, the weight matrix takes the form shown in Figure 6.

$$W = \begin{bmatrix} W_{1,1} & \cdots & W_{1,c} \\ \vdots & & \vdots \\ W_{r,1} & \cdots & W_{r,c} \end{bmatrix}$$

Figure 6. Weight Matrix of an Artificial Neural Network (Zaidi 2023)

- Bias: The network incorporates bias by adding an extra input element, typically denoted as x0 = 1, into the input vector. This bias corresponds to a weight and helps determine an output. Positively biased values amplify the overall input weight, whereas negative biases diminish the net inputs.

- Threshold: Determines output based on the following comparison:

$$\text{output} = \begin{cases} 1 & \text{if } \sigma(\text{net input}) \geq \text{threshold} \\ 0 & \text{if } \sigma(\text{net input}) < \text{threshold} \end{cases}$$

Evaluation of Prediction Models

To evaluate the performance of a model on a classifier data set, we consider the most common performance indices, namely, accuracy, precision, recall, and F-1 score. A confusion matrix is an evaluation grid of the accuracy of the prediction data for the test data. It provides a clear and detailed summary of how well a classifier is performing by comparing its predictions to the actual ground truth values in a dataset. It consists of four main components [12]:

• True Positives (TP): These are the cases where the model correctly predicted the positive class. In other words, these are the instances that are positive and were correctly classified as positive by the model. • True Negatives (TN): These are the cases where the model correctly predicted the negative class. These are instances that are actually negative and were correctly classified as negative by the model. • False Positives (FP): These are the cases where the model incorrectly predicted the positive class. These are instances that are negative but were incorrectly classified as positive by the model. False Positives are also known as Type I errors.

• False Negatives (FN): These are the cases where the model incorrectly predicted the negative class. These are instances that are positive but were incorrectly classified as

negative by the model. False Negatives are also known as Type II errors.

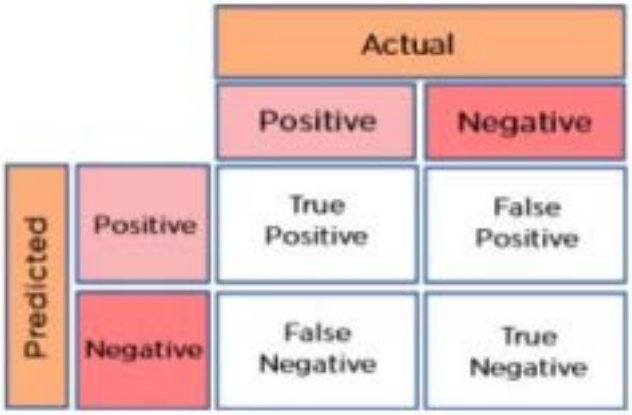

Figure 7. A Confusion Matrix (Simplilearn 2023)

Based on these components, various performance metrics can be calculated.

1. Accuracy: Accuracy measures the overall correctness of a classifier and is calculated by the formula: 9

$$A = \frac{T_P+T_N}{T_P+T_N+F_P+F_N}$$

2. Precision: Precision quantifies how many predicted positive instances were positive and is calculated by the formula:

$$P = \frac{T_P}{T_P+T_N}$$

3. Recall: Recall measures how many of the actual positive instances were properly predicted and is calculated by the formula:

$$R = \frac{T_P}{T_P+F_N}$$

4. F-1 Score: The F-1 Score is defined as the harmonic mean of the precision and the recall as a measure of the accuracy of a classifier, and is calculated by the formula:

$$F = \frac{2 \cdot P \cdot R}{P+R}$$

Experimental Results

Our initial objective was to develop a machine-learning model that could effectively predict the occurrence of a forest fire with only meteorological parameters. Even though we decided to ultimately phase out all work done with the Portuguese data set for reasons we mentioned earlier, we will still show our experimental results of all models run involving that data set. The low accuracies shown in Table 3 have been explained in further detail earlier in this paper.

Variation of Model	Accuracy
Portugal Dataset with Advanced Features	0.564102564102564
Portugal Dataset without Advanced Features	0.544871794871795
Merged Dataset with Advanced Features	0.689956331877729
Merged Dataset without Advanced Features	0.712418300653595

Table 3. Accuracy of Different Variations of our Dataset on a Random Forest Classifier (Note: An Advanced Feature is defined as data derived from the FWI System)

We ran our models on the cropped Algerian Forest Fire Dataset with only the four meteorological parameters and month of the year (as an integer). A random forest classifier model outperformed our other models for this approach. We achieved an initial baseline accuracy score of 86.486% with the Random Forest Classifier Model. For a Logistic Regression approach, we achieved an accuracy of 72.973%. Meanwhile, for a Decision Tree Classifier approach, we achieved an accuracy of 81.081% and for an Artificial Neural Network without tuning the hyperparameters, we got a 78.378% accuracy.

Model	Accuracy
Random Forest Classifier	0.864864864864865
Logistic Regression	0.72972972972973
Decision Tree Classifier	0.810810810810811
Artificial Neural Network	0.783783783783784

Table 4. Accuracy of Different Models on our Finalized Dataset

Because we achieved our highest initial accuracy with an untuned Random Forest Classifier Model, we decided to pursue an RFC when creating our final model. We used validation curves while hyperparameter tuning to test for the optimal parameters.

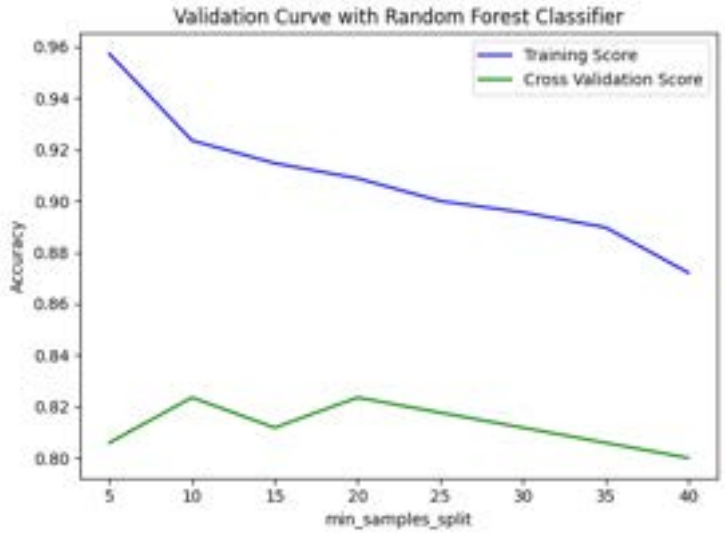

Figure 8. Validation Curve with Random Forest Classifier for min_samples_split

Figure 8 shows that 'min_samples_split = 20' would be the ideal value for min_samples_split. As min_samples_split gets larger from here, both the accuracy of the training score and cross-validation score decrease

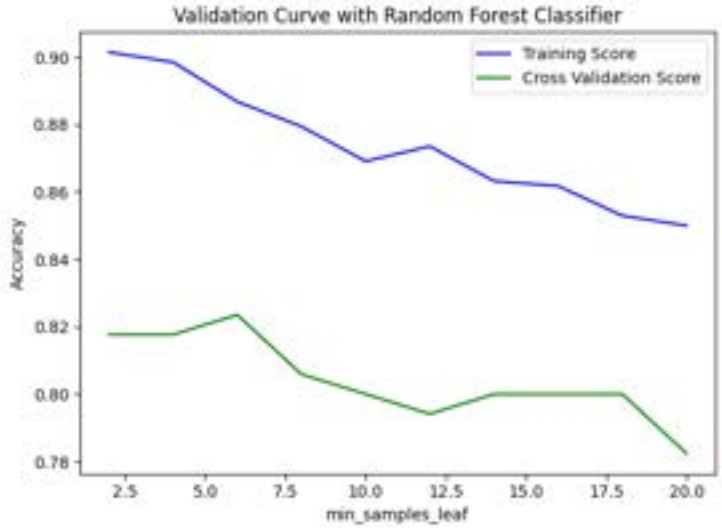

Figure 9. Validation Curve with Random Forest Classifier for min_samples_leaf

Moreover, Figure 9 shows us that a 'min_samples_leaf' value of 6 is optimal for this model since we achieve a peak Cross-Validation Score. Increasing the min_samples_leaf parameter from here only decreases the accuracy of the Training Score and the Cross Validation Score. We didn't run a cross-validation curve on any additional hyperparameters and thus used this version of the model as our final. The resulting training accuracy of the model with these tuned hyperparameters is 86.486, which is the same percentage as if it were without parameters. The reason for this is that the hyperparameters we found were chosen through cross-validation,

which is a mechanism used to decrease overfitting rather than improve training accuracy. The confusion matrix on the performance of our model is shown below in Figure 10, and the respective ROC curve is shown in Figure 11.

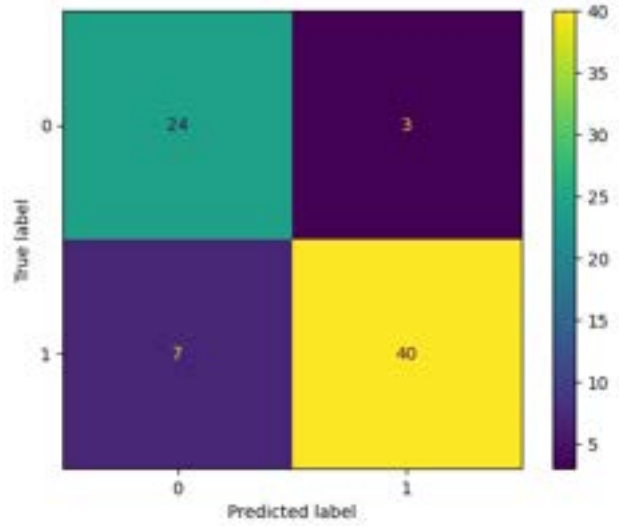

Figure 10. Confusion Matrix on Random Forest Classifier

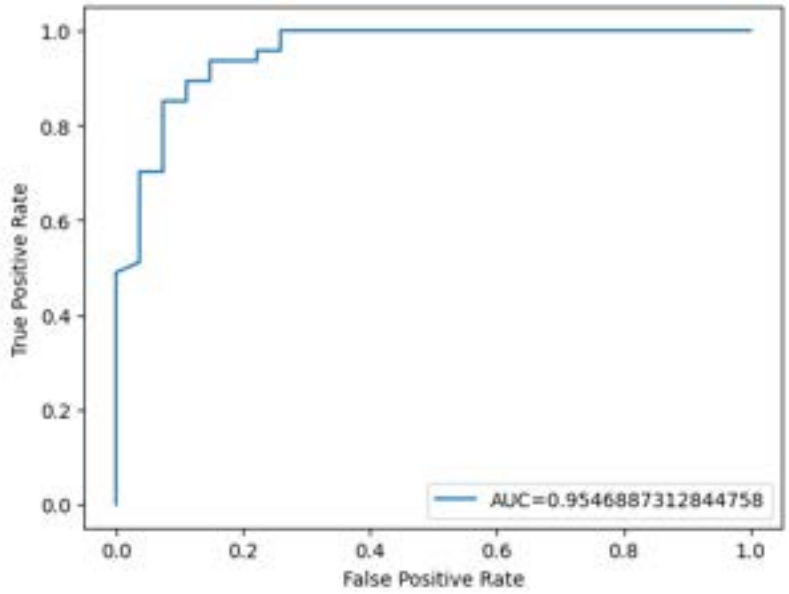

Figure 11. ROC Curve on Random Forest Classifier

The graph allows us to confirm that we indeed have a model largely free of overfitting. Table 5 shows the results of our performance metrics on the Random Forest Classifier.

Accuracy Score	0.864864864864865
F1 Score	0.888888888888889

Precision Score	0.930232558139535
Recall Score	0.851063829787234

Table 5. Random Forest Classifier vs. Different Performance Metrics

Conclusion

In this study, we trained a Random Forest Classifier (RFC) model that can accurately predict the occurrence of a forest fire with only four meteorological parameters. We trained and compared the performance of our Classifier with an ANN, Decision Tree, and Logistic Regression classifier, while also using cross-validation. The experiment shows a slight superiority of the RFC over the other models. We achieve an accuracy of about 86.486% and an F1 score of approximately 88.889%. Moreover, we have shown that the FWI Index is not a viable method for a forest fire prediction model due to its lack of information available. The results of this model could be used to assist forest management institutions by providing a mechanism to accurately prevent the occurrences of forest fires and encourage early action. Since we provide a probability of fire occurrence, fire management services can use this data to rank the severity of wildfires and more effectively manage areas at risk given resources.

Future Work

Building upon the insights and outcomes derived from the development of our Random Forest Classifier for forest fire prediction, several avenues for future research and enhancement present themselves, offering opportunities to further advance and refine the predictive model. For example, our model notably lacks versatility, as we limited our training data to only 244 instances from Algeria. If we had a larger dataset, we could have possibly achieved a more accurate model, and hopefully, on further research, it would be possible to create a more generalizable model with occurrences from a more diverse sample. There may be several inherent flaws with where we derived our training sample from, as several other factors could play a role in the occurrence of these fires. Therefore, a more comprehensive approach with more instances around the world would help broaden the scope of this model. We pondered this problem when creating this model, but we failed to pursue this or create a new dataset for our likings. Moreover, our model may be overfitting as our training data is very limited. For this to change, more research would have to be done on this topic.

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Parenting Styles' Impact on Teen Mental Health and Development By Rhema Yang

Abstract

Parenting styles profoundly influence adolescents' mental health and holistic development. This review examines the effects of authoritarian, authoritative, permissive, and uninvolved parenting on teenagers. Authoritarian parenting, marked by high control and low warmth, often results in anxiety, depression, and social impairments. Authoritative parenting, balancing warmth with firm boundaries, fosters emotional resilience and independence. Permissive parenting, though nurturing, can lead to issues with self-discipline and emotional dysregulation due to its lack of structure. Uninvolved parenting, characterized by emotional neglect, significantly risks adolescents' mental health and social skills. Understanding these impacts can guide parents, educators, and mental health professionals in supporting adolescents' well-being.

Introduction

Parenting styles are instrumental in shaping the mental health and holistic development of children and teenagers. In this context, development describes the physical, emotional, and social growth that children experience from birth through adolescence and into adulthood. As children grow physically, they also develop in their knowledge, skills, and behavior (Childcare). Mental health refers to emotional, psychological, and social well-being. It affects how one thinks, feels, and acts, and also helps determine how one handles stress, relates to others, and makes choices (World Health Organization). As adolescents traverse the stages of physical maturation, knowledge acquisition, skill refinement, and behavioral adaptation, the role of parenting styles becomes increasingly apparent. This influence extends beyond the immediate familial setting, impacting the trajectory of mental health, emotional resilience, psychological well-being, and interpersonal relationships. Recognizing the critical nature of parenting styles in adolescent mental health, this literature review delves into the characteristics and consequences associated with four primary parenting styles. This exploration aims to provide a nuanced understanding for parents, educators, and mental health professionals, shedding light on the intricate relationship between parenting styles and the well-being of the next generation. This review will inform readers of the parenting styles that are associated with the most positive mental health and development outcomes in children.

Authoritarian Parenting

Authoritarian parenting is characterized by high demands for obedience, low warmth, and minimal affection. This parenting style establishes a strict and rigid framework often enforced through hostile control or punishment (Stuck). Adolescents raised under authoritarian parenting are more likely to exhibit depressive symptoms and depression due to a lack of affection and an abundance of hostile control (King et al. 130). The harsh demands and punitive measures experienced in childhood contribute to the development of anxiety, shaping a mindset of

perfectionism and fear of punishment (King et al. 130).

Authoritarian parents tend to believe in the principle of "children should be seen, not heard," which means children should be quiet and well behaved (Perry). This can significantly limit a child's ability to make independent judgments and decisions; if children are constantly silenced, they will be hesitant to voice their thoughts and opinions (Stuck). Authoritarian parenting's impact on child development is extensive, with children often exhibiting aggression, social impairment, shyness, and difficulty with decision-making. This pattern can lead to poor self-esteem and a proclivity for rebellion against authority figures as children and adolescence grow older (Sanvictores et al.1).

The authoritarian approach has far-reaching consequences for the mental health of teenagers. Adolescents in such households may grapple with the long-term effects of minimal affection and hostile control, which may contribute to an increased risk of depressive symptoms and anxiety. The rigid structure and lack of autonomy can hinder the development of essential coping mechanisms and decision-making skills, posing challenges for the overall well-being of these children.

Kuppens and Ceulemans offer additional insights into the effects of authoritarian parenting on adolescent development (169, 178). This work suggests that authoritarian parenting correlates with higher levels of internalizing problems such as anxiety and depression among adolescents, limiting their opportunities for self-expression and autonomy (Kuppens & Ceulemans 169, 178). Furthermore, adolescents raised under authoritarian parents may exhibit externalizing behaviors such as aggression and defiance as coping mechanisms for the lack of warmth and support at home. These findings underscore the detrimental impact of authoritarian parenting on adolescent mental health, contributing to a range of behavioral and emotional difficulties that persist into adulthood. Hosokawa and Katsura provide additional insight into the dynamics of authoritarian parenting (11). This study emphasizes that authoritarian parenting, characterized by low warmth and high control, is associated with lower levels of child prosocial behavior in Japanese families (Hosokawa & Katsura 11). This suggests that the lack of affection and warmth inherent in authoritarian parenting styles not only impacts adolescent mental health but also influences children's social behaviors and interactions. The study underscores the importance of parental warmth and positive reinforcement in promoting healthy socio-emotional development in children, highlighting the detrimental effects of authoritarian parenting on various aspects of child well-being beyond mental health alone (Hosokawa & Katsura 11).

Authoritative Parenting

In contrast to authoritarian parenting, authoritative parenting fosters a nurturing and warm environment while maintaining firm limits and boundaries (Cherry). Parents practicing this style actively listen to their children's viewpoints, provide reasoning, and offer guidance for decisions and expectations (Stuck). Scientific evidence supports the positive effects of authoritative parenting on mental health (Vijay et al. 21). Teenagers raised in such environments are less likely to develop mental health issues, benefiting from the nurturing and warm

atmosphere that contributes to a well-balanced mental health and emotional state (Hayek et al. 2).

Authoritative parents encourage independence and critical thinking in their children, providing a supportive framework for their personal development (Cherry). This approach positively impacts child development, with children exhibiting self-confidence, happiness, and success. They tend to be more likely to display a strong sense of autonomy and an ability to navigate social relationships with ease (Cherry).

The authoritative parenting style lays the foundation for positive mental health outcomes by fostering an environment of warmth, understanding, and open communication. Adolescents in such households are equipped with the tools to navigate challenges, make informed decisions, and build strong social connections. This parenting style emphasizes the importance of mutual respect, autonomy, and emotional support, contributing to the overall well-being of teenagers.

Howenstein and colleagues reinforce the positive impact of authoritative parenting on adolescent mental health (62). This study suggests that adolescents raised by authoritative parents demonstrate better mental health outcomes, including lower levels of anxiety and depression, compared to those raised under other parenting styles. This aligns with the notion that authoritative parenting promotes independence, critical thinking, and emotional support, which are crucial factors in fostering resilience and well-being in adolescence. The study underscores the importance of authoritative parenting in creating a nurturing environment that empowers adolescents to thrive emotionally and socially (Howenstein et al. 62).

Permissive Parenting

Permissive parenting is characterized by warmth but laxity, where firm limits are not set, activities are not closely monitored, and mature behavior is not explicitly required. The impact on mental health is pronounced, with teenagers in permissive environments being more prone to anxiety and depression, often internalizing their problems and displaying withdrawal tendencies (Perry). Child development under permissive parenting reveals a lack of self-discipline, unruly behavior in school, diminished academic motivation, and a tendency to make decisions without parental knowledge, indicating a disregard for boundaries and authority (Perry).

Permissive parents typically adopt an indulgent approach, avoiding the establishment of clear rules or expectations (Cherry). While this approach may foster a sense of freedom, it often comes at the cost of structure and discipline, hindering the development of essential life skills in children (Aldhafri et al. 5). The lack of boundaries can lead to challenges in emotional dysregulation, decision-making, and the ability to cope with stressors (Cianico).

The permissive parenting style creates an environment where children may struggle to understand the consequences of their actions, impacting their ability to navigate challenges and make informed decisions (“Permissive Parenting: The Pros and Cons (According to 10+ Parenting Experts)”). Adolescents in permissive households may encounter difficulties in academic settings due to a lack of motivation and discipline (White). Additionally, the tendency to make decisions without parental knowledge can lead to challenges in building healthy

relationships and adapting to societal expectations (White).

Hinnant and colleagues add further depth to our understanding of permissive parenting (10). This study highlights that adolescents raised under permissive parenting styles often struggle with psychosocial adjustment, exhibiting higher levels of externalizing and internalizing problems compared to those raised under authoritative or authoritarian parenting styles. This suggests that while permissive parenting may foster warmth and freedom, the absence of clear boundaries and expectations can lead to difficulties in emotional regulation and decision-making among adolescents. Moreover, the lack of structure and discipline associated with permissive parenting may contribute to academic underachievement and challenges in interpersonal relationships. These findings underscore the importance of balancing warmth and guidance in parenting to promote healthy adolescent development and well-being (Hinnant et al. 10).

Uninvolved Parenting

Uninvolved parenting is characterized by providing only the basic necessities of food, shelter, and clothing, with minimal emotional support or guidance (Higuera). Uninvolved parenting may increase risks for poor mental health, low self-esteem, a quest for validation from external sources, emotional dysregulation, and even substance use (Higuera). In terms of child development, teenagers with uninvolved parents often struggle with social skills, exhibit social anxiety, possess low self-esteem, grapple with mental health issues, face academic challenges, and may encounter attachment issues (Stuck). Research suggests that these children may develop less effective coping skills, encounter difficulties in emotional regulation, and face challenges in creating and maintaining social relationships (Daley et al. 932).

Uninvolved parents may provide the basic necessities but are emotionally distant, offering minimal support or guidance in the child's emotional or academic pursuits (Higuera). This lack of involvement and emotional support can lead to significant challenges in the child's mental health and overall development. Adolescents in such households may seek validation from external sources, contributing to emotional dysregulation and potential engagement in risky behaviors, including substance use. Further, a study by McWhirter and colleagues found that children with uninvolved parents had more behavioral concerns as reported by the Child Behavior Checklist than children of permissive or authoritative parents (687).

Uninvolved parenting has a profound impact on the mental health of teenagers, with consequences extending to various facets of their lives. Adolescents in such households may experience a sense of neglect, leading to challenges in forming healthy relationships and a diminished sense of self-worth. The lack of emotional support can contribute to mental health issues, including anxiety and depression, as adolescents navigate the complexities of adolescence without the necessary emotional guidance.

Conclusion

In conclusion, parenting styles play a pivotal role in shaping the mental health and overall development of adolescents. Authoritarian parenting, with its rigid structure and minimal

affection, tends to foster anxiety, depression, and social impairments. Conversely, authoritative parenting, characterized by warmth and firm boundaries, promotes emotional resilience, independence, and well-being. Permissive parenting, while nurturing, often lacks the necessary structure, leading to issues with self-discipline and emotional regulation. Uninvolved parenting, marked by emotional neglect, poses significant risks to mental health, self-esteem, and social skills. These insights underscore the critical need for a balanced approach in parenting, emphasizing warmth, guidance, and consistent boundaries to support the healthy development and well-being of teenagers. By understanding the profound impact of different parenting styles, parents, educators, and mental health professionals can better navigate the complexities of adolescent development, fostering environments that nurture the mental health and holistic growth of the next generation.

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MMPs Role in Stem Cell Therapy for Cardiovascular Disease by Hanz J. Baek

Abstract

Stem cell therapy, with its capacity to regenerate healthy and functional cells, has been explored by scientists as a potential treatment for various diseases. For cardiovascular disease, obstacles including the lack of permanent engraftment and ventricular arrhythmia exist. Permanent engraftment is when a stem cell successfully engrafts itself into a tissue, bone, or organ for long periods of time while carrying out regular cellular functions, and ventricular arrhythmia is the irregular beating of the heart, specifically in the ventricles of the heart. These arrhythmias can translate to both too fast or too slow heartbeats. This review details the role and capabilities of Matrix Metalloproteinases (MMP) and stem cell therapy to treat cardiovascular diseases such as ventricular arrhythmias in the heart. It also explores the use of MMPs to differentiate stem cells to a certain level outside the body, with the potential of engrafting MMP-9 deficient cardiomyocytes into the heart. This review also specifies the capabilities of different kinds of MMPs and how they play a role in cardiovascular disease and stem cell differentiation. Last, we highlight the promise of induced pluripotent stem cells and how their distinct characteristics can be utilized alongside MMPs. Once scientists fully grasp the potential of MMPs in stem cell therapy for cardiovascular disease, they may be able to capitalize on the unique properties of MMPs to create a potential cure.

Introduction

Cardiovascular disease (CVD) is the world's leading cause of death, with an estimated mortality burden of 17.9 million people per year (World Health Organization). Men typically develop CVD at a younger age than women, but women have a higher risk of stroke at an older age (Bots et al.). Currently, there are three main interventional treatments for CVD, coronary angioplasty, a coronary artery bypass graft, and a heart transplant (Jamison DT et al.). Coronary angioplasties are used to unclog the heart's blood vessels, while a coronary artery bypass graft redirects blood around the clogged sections of coronary arteries. A coronary angioplasty requires a small balloon-like tube, called a catheter, to be inserted into the blood vessel, leading to bleeding or bruising beneath the skin where it was inserted (NHS). A coronary artery bypass graft surgery(CABG) involves the removal of a blood vessel from elsewhere in the body to use as a "graft", a surgically implanted piece of tissue, to redirect the flow of blood in the heart. This procedure involves risks of bleeding after the surgery, along with blood clots, infection, pneumonia, and kidney failure (John Hopkins Medicine, *Coronary Artery Bypass Graft Surgery*). A heart transplant involves the opening of the patient's rib cage and the implantation of a donor's heart, with risks of infection, bleeding, and blood clots that can cause heart attack, stroke, or lung problems (John Hopkins Medicine, *Heart Transplant*). Unfortunately, there is no cure for CVD, but the currently available treatments can help manage and alleviate symptoms (Cleveland Clinic). Stem cell therapy can be beneficial for CVD since it holds the potential to differentiate into new heart muscle cells and blood vessels, which may be able to replace damaged tissues and

blood vessels in the heart (Cona). According to the Becker's Hospital Review, stem cell treatment reduced heart attacks and strokes by 58%. Patients with high inflammation had an even higher reduced risk, 75% (Taylor Mariah). In relation to stem cells, MMPs can increase the proliferation rate of cardiac stem cells and change the rate of ventricular arrhythmia in the heart. In this review, we will highlight the promise of MMPs as a therapeutic target when utilizing stem cell therapy.

Overview of MMPs

Matrix metalloproteinases, also known as MMPs, are a family of zinc-dependent endopeptidases that participate in pathophysiological and physiological tissue remodeling (Yabluchanskiy et al.). MMPs were first discovered in 1962 by scientists Gross and Lapierre. Gross and Lapiere highlighted that MMPs act as a crucial collagenolytic enzyme that facilitates amphibian tadpole morphogenesis (Kessenbrock et al.). MMPs play a crucial role when it comes to tissue remodeling and organ development. By rearranging the extracellular matrix (ECM), they can change the interactions between substrate molecules as they relate to signaling pathways (Kessenbrock et al.). MMP-9 is one of the most researched MMPs, as it is responsible for the pathological remodeling process involved in inflammation and fibrosis in CVD. MMP-9 regulates tissue remodeling by degrading extracellular matrix proteins and triggering cytokines and chemokines, which are signaling proteins responsible for cell migration (Yabluchanskiy et al.). MMPs are characterized into 5 main groups based on their substrate specificity: collagenases, gelatinases, stromelysins, matrilysins, and membrane type (Yabluchanskiy et al.). Each MMP has unique properties, but this review will mostly focus on MMP-9, MMP-14, and MMP-16.

The myocardium, the muscular tissue of the heart, has a variety of ECM proteins such as lamins, fibronectin, and collagens. The most common protein found in the myocardial ECM is collagen, which provides sturdy strength to the cardiac muscle fibers. For people with CVD, the cardiac muscle undergoes tissue remodeling to preserve the heart's regular function, but this involves the breakdown of the collagen network and disrupts the skeleton for the cardiomyocytes. Many MMPs cleave collagen, including MMP-1, -2, -8, -9, and -14 (Yabluchanskiy et al.). MMP-9 has also been observed to increase rates of neovascularization by releasing an active form of a vascular endothelial growth factor. Additionally, it undergoes proteolytic degradation of proteins found in the basal lamina of the lining of blood vessels (Xu and Shi). A recent study demonstrated that treating a recombinant protein encoding only the catalytic domain of MMP-9 stimulated cardiac fibroblast migration, increased collagen synthesis, increased angiogenesis, and induced the formation of new blood vessels. This improved the development of cardiac fibroblasts into myofibroblasts (Yabluchanskiy et al.). MMP-9 seems to increase during wound healing and states of CVD, including myocardial infarction, atherosclerosis, and hypertension (Yabluchanskiy et al.). MMP-9 proteolytic properties help stimulate the immune response to start pathogenesis and worsen disease progression. Some regulators of MMP-9 at the transcriptional level include E-26(Ets) transcription factors, NF-kB,

polyomavirus enhancer A-binding protein-3(PEA3), and serum amyloid A-activating factor(SAF)-1(Yabluchanskiy et al.). Although MMPs are beneficial, they can have negative effects as well. For example, 836GA, an MMP-9 polymorphism, was seen to induce aortic stiffness and hypertension (Yabluchanskiy et al.).

Another heavily researched MMP is MMP-14. MMP 14 is responsible for embryonic tissue formation by producing collagen fibrils out of the cell surface (Taylor et al.). Cardiac macrophages, which function as the main immune cells of the heart, increased the expression of MMP 14 a week after myocardial infarction (MI) (Alonso-Herranz et al.). MMP 14 is upregulated after infarction while other MMPs, such as MMP 9 and MMP 13, were downregulated (Alonso-Herranz et al.). Ultrasounds of the heart identified that macrophage-inactivation of MMP 14 prevented left ventricle dilation and improved left ventricle dysfunction after myocardial infarction (Alonso-Herranz et al.). Scientists have also shown that MAC-MMP 14 knockout (KO) mice have a protected microvasculature network and improve myocardial oxygenation after ischemic injury (Alonso-Herranz et al.).
Epithelial-to-mesenchymal transitions are particularly beneficial due to their ability to repair damaged tissues. Regulation of MMPs have a significant effect on the heart, but unfortunately, there are still many unanswered questions about MMPs.

MMP-9 can also act as an anticancer agent. Cancer research is primarily focused on the overexpressed molecules, which contribute to cancer progression (Mondal et al.). MMPs are highly expressed in every stage of cancer development, acting as a biomarker for many types of cancer. Therefore, inhibition of MMPs has the potential to successfully target and eliminate cancer. This theory has been proven by some scientists who claim that MMPs act by inhibiting cancer cell growth while others claim that MMPs decrease tumor proliferation by using apoptosis. In conclusion, both iPSCs and MMPs hold incredible promise in the medical field and it's only a matter of time before we see the emergence of modern solutions to all kinds of other diseases.

Overview of Stem Cells and Stem Cell Therapy

Stem cells are one of the most well-studied topics in the medical field. Stem cells are undifferentiated cells with the potential to differentiate into different cell lines within the body, including blood cells, tissue cells, and muscle cells. Stem cells may be pluripotent or they may be adult stem cells. Pluripotent stem cells have the capacity to differentiate into greater cell lines. A type of pluripotent stem cell is an embryonic stem cell, which is derived from the inner cell mass of the blastocyst-stage embryo (Lee and Lee). Another type of pluripotent stem cell is the induced pluripotent stem cell (iPSC). iPSCs are reprogrammed cells that are obtained by isolating somatic cells, such as skin or blood. They are then exposed to specific transcription factors like Oct4, Sox2, Klf4, and c-Myc (OSKM) which revert them to an embryonic stem cell state (Al Abbar et al.). An advantage of using iPSCs is it avoids the ethical issues of destroying human embryos. iPSCs retain the genetic material from where they were collected, which allows for disease modeling. Adult stem cells like mesenchymal and hematopoietic stem cells are

sometimes difficult to work with, as they are further differentiated. One major application related to stem cell therapy in regard to CVD is cardiomyocytes, which facilitate contractions in the heart. Stem cell therapy is crucial as cardiomyocytes lack the ability to proliferate once they reach adulthood (University of Pittsburgh Health Sciences). The stem cell environment and various transcription factors play a critical role when during the differentiation of a stem cell. Inside the microenvironment, multiple external signals, cell-to-cell interactions, and chemical factors are transmitted between surrounding tissue (Towns and Jones). Currently, stem cell therapy has shown therapeutic promise for illnesses such as Parkinson's disease, stroke, burns, cancer, and spinal cord injuries (Mayo Clinic). Unfortunately, stem cell therapy has its limits. For example, stem cells face the potential of engraftment rejection and permanent engraftment. When scientists administer stem cells from foreign donors, the body's natural immune response may cause rejection of the stem cells, disabling them from successfully engrafting onto the target tissue. iPSCs have the potential to overcome these concerns.

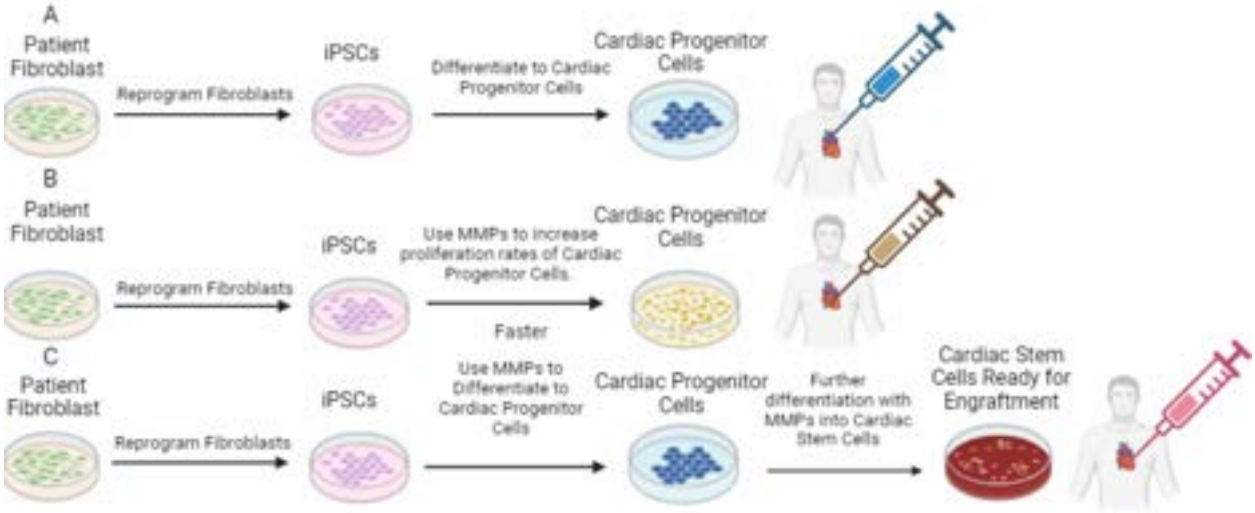

Figure 1: Therapeutic approaches for stem cells in cardiovascular disease

Figure 1A) After reprogramming fibroblasts, iPSCs, which we can further differentiate into cardiac progenitor cells, are directly injected into the heart. 1B) Instead of simply differentiating iPSCs into cardiac progenitor cells like in Figure 1A, MMPs are used to increase the proliferation rate to ultimately increase the amount of cardiac progenitor cells available. It's important to note that this process allows us to create cardiac progenitor cells at a faster rate. 1C) MMPs can also be used to differentiate iPSCs into cardiac progenitor cells. From here, they can be used to further differentiate them into cardiac stem cells ready for engraftment. This extra step decreases the possibility of mis-differentiation once the cells are engrafted into the heart. This figure was created using BioRender.com.

How we can Utilize MMPs to Improve Stem Cell Therapy for Cardiovascular Disease

Stem cell niches are the microenvironment in which stem cells live and receive stimuli that determine their fate (Guo et al.). The stimuli involve cell-to-cell and cell-matrix interactions

that activate genes and transcription factors. These code for a specific pathway for the stem cell to differentiate through. MMPs can rearrange the extracellular matrix (ECM) and alter signaling pathways through pleiotropic interaction with substrate molecules. In vitro experiments have shown that hepatocyte growth factors (HGF) play a crucial role in myocardial differentiation of bone marrow-derived stem cells (BMSCs), but these growth factors cannot proliferate (Guo et al.). Another factor that promotes stem cell differentiation into cardiomyocytes is the insulin gene enhancer binding protein ISL-1 (Guo et al.). MMPs hold the potential to alter the stem cell niche; therefore, using this technology, scientists can administer progenitor cells for engraftment. The niche in the heart has multiple cell types, such as cardiac stem cells, fibroblasts, capillaries, and progenitors. These cells, along with the ECM, hold the niche together, providing a safe environment for the maintenance and function of cardiac stem cells.

MMPs can also be used to culture iPSCs, which can be used to speed up the differentiation process. From there, the cardiac progenitor cells can be administered to the patient in a timely manner, which is an obstacle that has yet to be overcome as the administration process is very time-consuming (Figure 1B). A downside of this is that if scientists don't completely differentiate the stem cells, the cell therapy that is administered will be ineffective because cardiomyocytes aren't the only type of cell the stem cells could become. Scientists may be able to partially differentiate cardiac progenitor cells into cardiac stem cells outside the body. When inserted into the heart, there can be greater assurance the progenitor cells will only differentiate into cardiomyocytes (Figure 1C). Stem cells have a longer life expectancy than regular cells, increasing the chance for genetic mutations. This can potentially lead to cancer (Harvard Stem Cell Institute). Although this may seem like a harmful outcome, if scientists can somehow harness the rapid replication rates of cancerous cells and implement them into cardiac stem cells, proliferation rates wouldn't be much of a problem. In regards to stem cell therapy, MMP-9 has been proven to regulate the differentiation of cardiac stem cells through autophagy and epigenetic modifications (Yadav and Mishra).

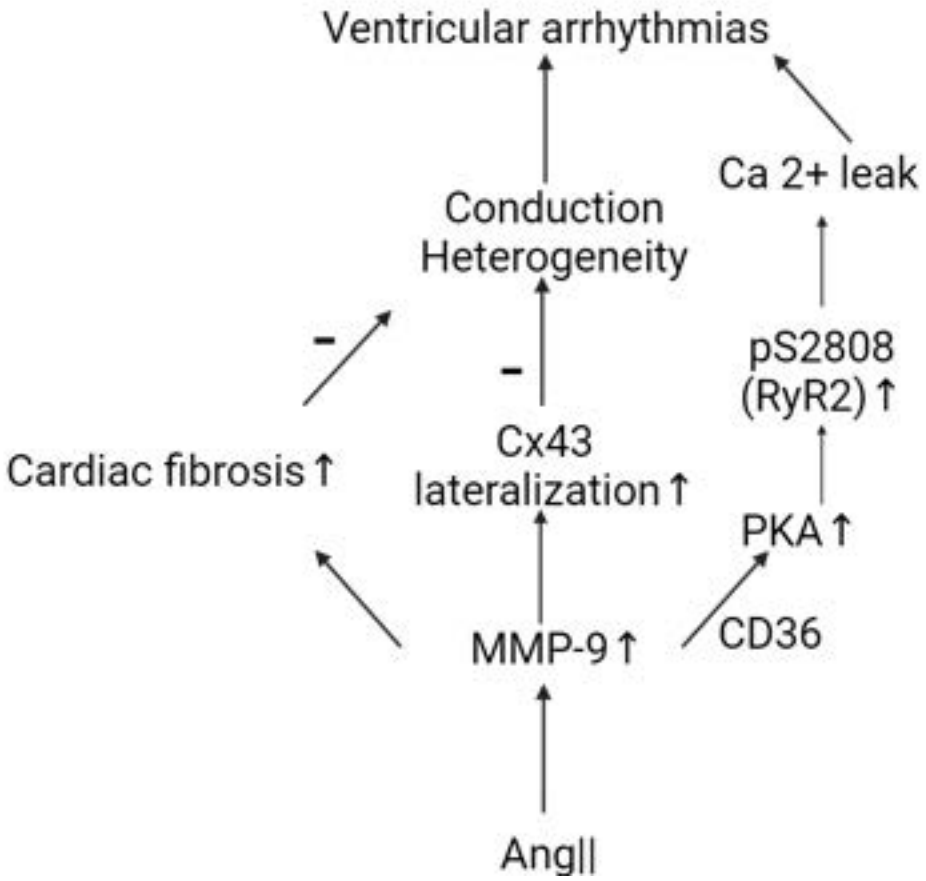

Figure 2: The pleiotropic effects of MMP-9

1. Adapted from (Weng et al.)
2. MMP-9's pleiotropic effects regulate and inhibit a variety of proteins and signals. MMP-9, through CD36 degradation, regulates the phagocytosis by macrophages and neutrophil apoptosis (DeLeon-Pennell et al.). As seen in the figure, MMP-9s can regulate a variety of proteins and processes through the degradation of CD36.

MMP 9's Therapeutic Potential to Treat Cardiovascular Disease

Previous studies have shown that deficient MMP-9 leads to arrhythmia in mice, suggesting it is a promising therapeutic target for humans. Ventricular arrhythmia is the abnormal beating of the heart. Current research has not demonstrated an association between stem cell therapy and arrhythmias. However, scientists have found a link between MMPs and ventricular arrhythmia. MMP-9 deficiency was proven to prevent ventricular arrhythmia in mouse models (Weng et al.). The decrease of MMP-9 was additionally found to prevent the leakage of calcium ions, which down-regulates the phosphorylation of RyR2 and protein kinase A (PKA). This ultimately reduces ventricular arrhythmia in mouse-isolated ventricular cardiomyocytes (Weng et al.). As shown in Figure 2, the upregulation of MMP-9 has a variety of downstream effects, such

as regulating the rates of cardiac fibrosis, Cx43 lateralization, and PKA. As a result, targeting MMP-9 in isolation may not be as promising. MMP-9 alters the regulation of other chemicals, which may have harmful effects. Instead, scientists can target CD36, PKA, or RyR2, which are all chemicals regulated based on MMP-9 regulation. On the contrary to ventricular arrhythmia, scientists have found a link between stem cell therapy and myocardial infarction. Using all these properties and utilizing them in stem cell therapy, scientists may be able to find a cure for CVD in the future.

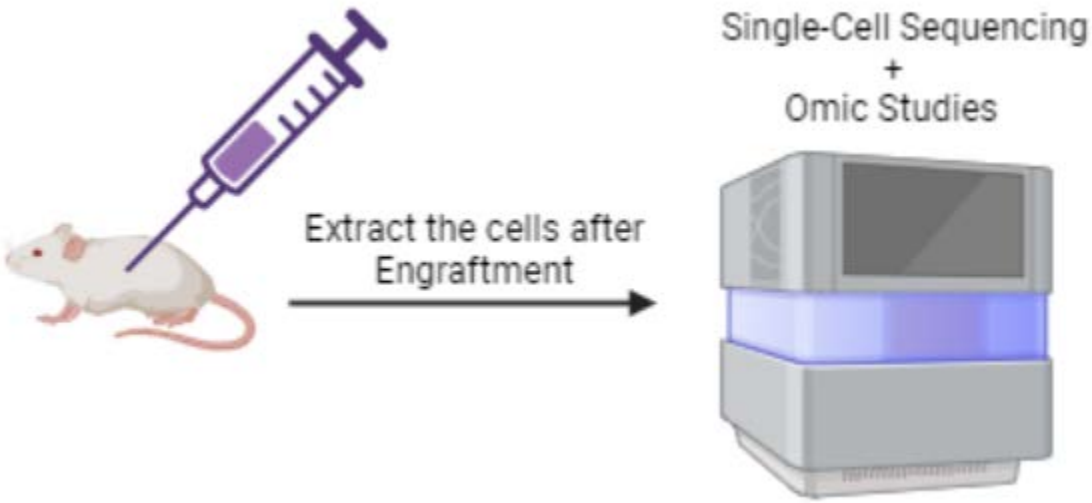

Figure 3: Sequencing approaches to study MMPS.
Using a sequencer, scientists can extract the cardiomyocytes and perform sequencing and omic studies. With omic studies, we can analyze the protein regulation found in the cells. This figure was created using BioRender.com.

Unanswered Questions/Proposed Experiments

Even though stem cells have been such a hot topic in modern medicine, there are still unanswered questions for scientists to discover. Although scientists have demonstrated links between MMPs and their effects on CVD, there is a lack of research on the link between MMPs and stem cells. Other related questions include how MMPs nurture a stem cell to differentiate into a specific cell. Scientists will also need to confornt over-proliferation when utilizing MMPs to regenerate cardiac tissue. This could happen due to a multitude of reasons, including the cell type being cancerous and causing it to replicate uncontrollably.

Researchers have a clear understanding of which cells make up the niches inside the heart responsible for the differentiation of cardiac stem cells, but the individual role of these cells remains unclear. Sequencing may allow scientists to better understand what is causing the differentiation process of cardiomyocytes in a stem-cell niche. For example, they may use a sequencer to see if MMP-9 or 14 is down or upregulated somewhere. Sequencing can also inform scientists which signals or molecules a cell turns on or off to differentiate into a fibroblast, skin cell, cardiomyocyte, etc. Using single-cell sequencing, we can analyze what

effect MMP-9 deficient cardiomyocytes have on other heart cells once engrafted. We can combine this experiment with proteomics to see what specific proteins, like CD36, PKA, and RyR2 are regulated after we regulate the amount of MMP-9 in our hearts (Figure 3).

Studying these proteins gives insight into how ventricular arrhythmia functions and what causes it to occur. Other various types of unanswered questions include what type of molecular sequences or signals are activated by MMP-9 and MMP-14, and what would happen if there is too much signaling. Finding the correct number of cells to engraft into the heart is also another challenge. By gaining more information about MMP cell specificity, scientists will be able to use MMPs as a targeted therapy for CVD. Additionally, studying if anything in the heart affects the expression of MMPs may help us understand how we can use MMPs as a cure. Finally, if scientists discover whether or not MMPs can increase the differentiation rates of stem cells, they could apply MMPs to a whole range of medical uses.

Conclusion/Discussion

Cardiovascular disease is the leading cause of death worldwide. Scientists have studied a variety of ways to find potential cures and treatments for this disease. Stem cells are one of the most promising methods discovered. Scientists primarily use iPSCs, as they're easily accessible and have much-needed properties like their pluripotent capabilities and accessibility. One disadvantage to these is that the retroviruses used to create them are associated with cancer (Al Abbar et al.). The promise of MMPs as a therapeutic target has been suggested, but they have yet to be extensively studied. The future of iPSCs looks bright as with time and further research, scientists may be able to develop clinical treatments that can cure CVD. iPSCs are promising as they not only hold potential in CVD, but also in a variety of other diseases such as spinal cord injuries, Parkinson's disease, and lateral sclerosis.

MMP-9 is not the only MMP with potential in this field. MMP-14, which is secreted by macrophages, allows for the endothelial-to-mesenchymal transition of the heart after myocardial infarction (Lim). MMP-14 is responsible for the differentiation of mesenchymal stem cells, which aid in pathogenic cardiac remodeling, fibrosis, and cardiac stem cell proliferation in the damaged heart (White et al.).

One issue when it comes to proliferation is over-proliferation, which may be countered with different cell-signaling-like growth factors. Scientists can also co-administer MMP-14 so that it enhances stem cell differentiation. MMP-16 has been shown to reduce the rate of cell migration which ultimately reduces MMP-16 expression and activity. This reduction in activity could have positive effects like higher rates of cardiac regeneration and progenitor cell transplantation (Jovic et al.).

MMPs already have relations to CVD, and they hold the potential to create treatments for it. With the properties of MMPs, we can alter the environment in which a stem cell differentiates to control what cells our stem cells differentiate into. MMP-9 can control the differentiation of cardiac stem cells, MMP-14 allows for endothelial-to-mesenchymal transition for heart cells, and MMP-16 can upregulate cardiac regeneration and progenitor cell transplantation. Some of the

main capabilities of MMPs include mediating the differentiation of stem cells, remodeling all types of tissues, and rearranging different EMCs. In conclusion, both iPSCs and MMPs hold incredible promise in the medical field and it's only a matter of time before we see the emergence of modern solutions to all kinds of diseases.

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Revolutionizing Exoplanet Discovery: A Machine Learning and Artificial Intelligence Approach by Aryan Khandelwal

Abstract

In recent years, there has been a marked increase in the number of cataloged exoplanets with the rapid advancement of technology. Hence, it has become more essential to have a systematic identification and assessment of their astrobiological potential and habitability.

Looking at planetary habitability, it can simply be defined as the physical conditions present on Earth and the respective characteristics of the Sun and Solar System that are required to be present on an exoplanet in order to support life. To sustain human life, it is crucial for a habitable exoplanet to support liquid water. However, a planet's ability to maintain liquid water is the end result of a complex set of Planetary and Galactic processes.

Keeping this in mind, this Research paper aims to provide a detailed understanding on the several factors that are required to characterize a habitable exoplanet as well as the several methods used to detect these celestial bodies. We firstly discuss the key factors that are required to term an exoplanet as habitable such as Luminosity, SED and its physical properties. Subsequently, we discuss the key methods of discovering exoplanets, which include Radial Velocity method, Transit Technique, Direct Imaging, and Secondary Eclipse.

Later on, we provide a survey of the current Machine Learning methods. The key Machine Learning algorithms and methods such as Bias Handling and Dimensionality Reduction are also discussed in this section. Lastly, we introduce a new concept of creating an autonomous model which incorporates Artificial Intelligence to detect exoplanets. The main aim of this model is to make it publicly accessible, data-rich, as well as remotely efficient towards detecting exoplanets. We propose an extensive framework by providing its concept, implementation, futuristic opportunities, merits and risks associated with it.

Introduction

Exoplanet science can be defined as that branch of science which deals with the search and identification of potentially habitable celestial bodies which remain away from the solar system. These celestial bodies are termed as exoplanets. There are several factors upon which an exoplanet can be termed as habitable. Nonetheless, its habitability can be narrowed down and defined as the planet's ability to maintain liquid water. As life beyond Earth is unknown, planetary habitability is an extrapolation of the conditions on Earth and characteristics of the Sun and Solar System which appear favorable to life's flourishing. However, determining their habitability can be a tedious task for humans as our knowledge on exoplanets is limited in several ways.

According to several astronomers and scientists, the reason for it being a challenging process is due to the fact that several of the planetary factors may change with the age of the star, consequently affecting the habitability of a planet over time. In addition to these properties, the habitability of a planet is also influenced by the properties and processes of the planet itself.

Although subsurface liquid water and several stellar characteristics can be readily determined through remote-sensing telescopic observations, it is far less likely to obtain realistic data from these methods. Whether a planet will emerge as habitable depends on the sequence of events that led to its formation, which could include the production of organic molecules, delivery of materials during and after planetary formation, and the orbital location in the planetary system.

In this research paper, we discuss the larger context of exoplanets by providing a detailed description of the factors that affect its habitability, namely the Planetary and Stellar Characteristics. Later on, we provide a detailed survey on the current detection methods and how they serve as a solution towards the exoplanet discovery task. Furthermore, we discuss the Machine Learning methods and how they have shaped the current exoplanet discovery process. Lastly, we propose a new ideology towards searching for these celestial bodies which involves the usage of Artificial Intelligence and aims to further enhance our knowledge not only on exoplanets, but also about space in its entirety.

Background

Previously, there have been several methods to detect exoplanets. However, it is crucial to understand what are the factors that play a role in determining a planet's habitability. In this section of the research paper, we discuss the key planetary and stellar characteristics that help in terming an exoplanet as "habitable".

Planetary Characteristics for Habitability

Habitability of any celestial body depends on a lot of factors. The planet's environment, mass, orbit, surface, interior and atmosphere set the stage for its habitability. Once life has evolved on the planet, it becomes a habitable world where the planetary processes impact the habitability over a constant duration of time. Below, we describe several of the key planetary characteristics and processes that support habitability, and briefly describe our ability to likely observe these characteristics on exoplanets.

Atmospheric Properties

The presence of an atmosphere around a celestial body promotes habitability by protecting the surface from biologically damaging radiations, shielding surface liquids against photolysis, maintaining barometric pressure against boiling, and also serving as an exchange medium for various existing metabolites. An atmosphere is an envelope of gas that surrounds a celestial body, and is retained due to the force of gravity acting on it. Keeping in mind that habitability is the ability to support and maintain liquid water on a surface, it is essential to have an atmosphere as water only remains liquid under a narrow range of temperature at a given pressure. Without adequate pressure and temperature, the water will irreversibly evaporate or sublime away. For synchronously rotating planets, adequate atmospheric pressure is of utmost importance as the day-night temperature differences can grow large, which can result in an

atmospheric collapse on the night side. To maintain liquid water on the surface, appropriate surface temperatures are maintained through a delicate balance between the incoming and absorbed radiation from the star and the emitted thermal radiation from the planet. Maintaining the right surface temperatures requires having the right amount and combination of atmospheric gasses. CO2 is perhaps the most familiar greenhouse gas, which helps to maintain surface temperatures on Earth. To keep planets habitable despite their difference in the received flux, the long term regulation of CO2 in the atmosphere via silicate weathering cycle is thought to be one of the methods to achieve the desired solution.

With respect to the climate of habitable planets, H2O is the most interesting atmospheric constituent, and not because it is a prerequisite for life (Kumar Kopparapu et al.). On a habitable planet like Earth, the variations in temperature and atmospheric pressure allow water to exist in all of its three thermodynamic phases simultaneously in the atmosphere, ocean, and surface. Water vapor is a strong greenhouse gas which acts to warm the planet. High altitude ice water clouds, similar to Water Vapor, act as strong greenhouse gasses and warm the celestial body. On the other hand, Liquid Water Clouds are highly reflective and cool the planet. Albedo can be defined as the amount of light that is reflected from the surface, compared to the total sunlight that falls on it. Keeping this concept in mind, the condensation of water on the surface as snow or ice raises the albedo and keeps the planet cool. On an important note, the water-vapor greenhouse feedback and ice-albedo greenhouse feedback are both positive. This mainly signifies that they can potentially amplify climate perturbations, potentially leading to climate catastrophes, runaway glaciation, and the end of habitability. While water is of course critical for the existence of life, water has an inherently destabilizing force on the climate system.

Magnetic Fields

Magnetic Fields are an important factor when considering the habitability of a celestial body, as they protect the planets from losing volatiles through several stellar wind interactions, deflecting harmful radiation and providing a source of energy that can be harvested by living organisms.The magnetic umbrella is the outermost region of a celestial body which protects the planet from harmful radiations. However, this phenomenon is still debated, as the magnetic field may also increase the interaction area with the solar wind, which could prove detrimental towards the atmosphere of the planet (Kumar Kopparapu et al.). The ability to measure magnetic fields at such large distances may be challenging. However, with the recently proposed techniques, it has become much easier to define and calculate whether they reside within our habitability zone.

Planetary Interior and Geological Activity

The interior of a celestial body plays a critical role in determining the habitability of the planet. A dynamic and active interior can drive the generation of magnetic field, interior resistance, and outgassing, which are a necessity to maintaining and producing a secondary atmosphere. The removal of gas through the process of heating is known as outgassing. Keeping

this in mind, tectonic activity on a planet can significantly influence the habitability of an exoplanet through several cycles of volcanic outgassing and consequent weathering of the released gasses. It creates a weatherable topography which has a long-term effect on the evolution of the climate and surface temperature. Furthermore, it can prove to be detrimental towards habitability, as the tectonic activity similar to that of Earth facilitates an efficient water cycling between the surface and interior.

Planetary interior properties are challenging to determine observationally, yet possible. Constraints on planetary interior structure can be yielded through theoretical precise characterization of the planetary system's orbital state, including the rigidity of the planetary surface and the tidal deformation. Hints of the planetary interior composition may also be possible to obtain from measurements of atmospheric and cloud composition, which may point to various volcanic outgassing sources. Transmissions or direct imaging observations may reveal compositional changes in the atmosphere, which are indicative towards ongoing volcanic activity.

Solid Surfaces

For an exoplanet to be habitable for humans and other forms of life, it is crucial to have a solid surface as it promotes habitability by providing stability and protection from various types of radiation. Furthermore, it provides a surface for chemical reactions to take place. Rocky planets and planets with frozen layers in contact with atmospheres and liquids provide an interface where organisms and nutrients can be concentrated in a two-dimensional plane. Solid planetary cores with sufficient density that generate internal heat from radioactive decay favor habitability as the plate tectonics recycle elements essential for a regenerative biosphere. Hence, the habitability of an exoplanet correlates positively with the solidity of the celestial body.

Effect of Mass and Radius

A planet's mass impacts a celestial body's habitability in multiple ways. It provides radiogenic heating to drive volcanic activities within the planet's core, as well as the generation of a magnetic field which is a key parameter that determines atmospheric retention. The process of controlling and retaining a planet's atmosphere by its gravitational force is known as Atmospheric retention. Mass is also a key parameter which plays a crucial role in this process, as the retention is interdependent on the radius and the amount of solar radiation received. The vertical distance above the surface, where the density or pressure decreases by a constant amount is known as Atmospheric Scale Height. Keeping this in mind, the planetary mass has the ability to control this phenomenon, which can change the rate the planet radiates to space and modify its climate.

Planetary radii and masses can be relatively straightforward to measure, depending on the technique used to detect the planet. If the planet transits and the stellar radius are well-known, then the Exoplanet radius can be straightforward to measure. On the other hand, size can be extremely challenging to observe if the planet does not transit. However, these masses can be

measured using techniques such as transit timing variations, astrometry, and radial velocity measurements combined with the planetary system inclinations.

Stellar Characteristics for Habitability

The host star's characteristics have a huge influence on the planet's environment and habitability. The stellar mass and radius determine many of the star's fundamental properties, such as temperature and lifespan. The stellar spectrum and activity levels have an influence on the atmospheric escape and climate, providing the most abundant surface energy source for a majority of exoplanets in the HZ (Kumar Kopparapu et al.). Stellar luminosity evolution drives strong climate change and may result in atmospheric loss, which is a composition change and acts as a threat to habitability. In this subsection, we discuss the key stellar characteristics for habitability, and how they often affect the environment and work positively towards defining the habitability of an exoplanet.

Activity levels

Stellar activity is produced through the magnetic field interactions, which act as a function of the internal convection of the star and its rotation rate. The stellar mass and age of the star are also a few of the factors which affect the level of stellar activity. Due to the differential rotation at the boundary between the radiative inner and outer zone in certain stars, a stellar magnetic field is created via a process known as shearing, which is an effect of the distortion of the image due to deflection of light by matter. The generation of the magnetic field is intimately linked to the stellar rotation, and this characteristic evolves as the star ages. Stellar activity levels and frequency are relatively easy to measure using broadband photometry. However, in-depth spectral information on the flares emitted requires UV spectroscopy from space based platforms such as GALEX or HST.

Luminosity, SED, and Age

The energy emitted by the host star, and the energy received by the exoplanet, plays a detrimental role in determining the habitability of an exoplanet. The measure of the total energy that the star emits per unit time is known as the Luminosity of the star, and it depends on the star's size and emitting temperature. The stellar luminosity controls the energy received by a planet, and helps in determining the required Habitable Zone. By generalization, it is known that smaller, cooler stars have lower luminosities than the larger, hotter stars. More massive stars support their higher luminosities by burning their deposited atomic fuel at a higher rate, but can't transfer the additional fuel to the core as efficiently as smaller stars, and hence have significantly shorter life spans. The rate of luminosity evolution depends on stellar mass, with larger hotter stars naturally brightening more rapidly than smaller, cooler stars.

The spectral energy distribution [SED] is the amount of radiation emitted by the star as a function of wavelength. It is heavily dependent on the emitting temperature of the stellar photosphere, while the wavelength of peak stellar emission being inversely proportional to the

emitting temperature. The relative SED of the star can also strongly influence the climate system. This is primarily because the surface reflectivity and light scattering are all sensitive to the changes in the SED. The relative SED may also strongly influence biology, as photosynthesis plays a crucial role in the biosphere of Earth.

Exoplanet Detection Methods

As the bridge between the digital world and the field of astronomy becomes narrower, it is essential to look back on the previous methods of exoplanet detection and develop an understanding of the tools, techniques and results presented in this paper. In this section, we will be looking at the various traditional methods of researching distant stars and celestial bodies. These include NASA's Exoplanet Exploration (ExEP) Program, the Kepler telescope, Radial velocity, Microlensing, Direct Imaging, and Transit time. As we are embarking upon a groundbreaking time for Exoplanet discovery, we aim to provide a basic understanding of these traditional methods and use the concepts to further build upon a digital transformation in astronomy.

NASA’s Exoplanet Exploration Program (ExEP)

NASA's Exoplanet Exploration Program (ExEP) science and missions oversees the implementation of NASA's ambitions for the finding and comprehension of planetary systems orbiting neighboring stars (NASA). The primary goal of undertaking this program is to count and take a census of the unique planetary systems in our Solar system and search for similar Solar systems. At the end, we aim to discover Earth-like planets and characterize their habitability through this program.

Over the course of time, the ExEP aims itself to achieve two far-fetched goals. The first goal being to understand the life cycle, formation, and the composition of the exoplanets and their systems. The second objective is to determine whether exoplanets may be habitable and how frequently they occur by using the data gathered in the first aim. Through these two goals, it guides towards answering the question “Are we alone?” and the likelihood of biological life (Sturrock et al.). A key component of the ExEP is the combination of several programs and the inclusion of several telescopes. Through the Spitzer and Hubble telescopes, researchers using NASA data have been able to characterize several exoplanets through the transit in front of their parent star. Moreover, the spectrometry and the astronomical tools used in the WFIRST mission can directly produce an image of several exoplanets and characterize them based on our own system.

As the digital transformation in astronomy and astrophysics is underway, the ExEP serves as a platform where the census of several planetary systems are readily available.The public availability of this data allows the acceleration and identification of exoplanets at a fast-paced rate, where researchers from corners of the world join hands and work towards achieving a joint goal.

The Kepler Space Telescope

In 2009, one of the most influential planet-hunting telescopes was launched in space, serving as our hope to find exoplanets. To date, it has been the most successful telescope in the discovery of Exoplanets. The Kepler Space telescope has been designed to survey a part of the Earth's region of the milky way, aiming towards finding the next habitable celestial body. One of the key instruments used in this device was the photometer, as it gazed and monitored more than 100,000 stars in a fixed point of view.

The Kepler Space telescope was launched by NASA in 2009, where it was tasked with two objectives : to explore the structure and diversity of the exoplanet systems ; to determine the census of the exoplanets that reside within the habitable zone (Nasa). The functioning of the telescope can be described as a 2 - way step method. 1. As soon as the Kepler data is received, raw light curves are constructed, where the brightness is set as the measure. This step serves towards finding planet candidates. 2. Once the Kepler data and raw light curves are constructed, the false positives need to be amended and removed. Hence, more advanced-ground based telescopes are used to complete this purpose and helps in confirming the presence of the exoplanet candidates. For precautionary methods, the false positives are run through several different detection methods to clear the possibility of having an error within the system (Sturrock et al.).

As of June 2023, the Kepler data consists of 530,506 stars and 2,778 confirmed exoplanets (Nasa). The Kepler mission was successful because of its exceptional photometric accuracy, the duration and continuity of the observations, and the quick data sampling, which produced insights into the long-term behavior of many stellar targets and light variation well below the millimagnitude level.One could argue that in the past few years, Kepler has not only revolutionized our understanding of exoplanets but also the area of study for stellar astronomy.

Radial Velocity

The first method for detecting multiple planets orbiting main sequence stars was radial velocity (RV) detection. It is entirely dependent on the identification of changes in the central star's velocity brought about by an exoplanet's shifting gravitational field as it revolves around its own star. Ultrastable spectral reference frames and high resolution spectroscopy are used to detect the radial motion (both forward and away) of the star (Sturrock et al.). The radial velocity amplitude is sensitive to large planets that orbit close to their small parent stars because it is inversely proportional to both the mass of the star and the planet's orbital distance. Increase in radial velocity can be said as a result of the increase in mass and orbital speed. Due to the frequently unknown orbital inclination, the minimum mass that can be determined from the RV measurements is uncertain. Other planetary characteristics that can be revealed by the measurements include the planetary orbital period, eccentricity, and mass. **Fig. 1** illustrates the gravitational pull that an orbiting planet tugs on its host star. This causes an effect known as "Doppler Shift" in the star's spectra.

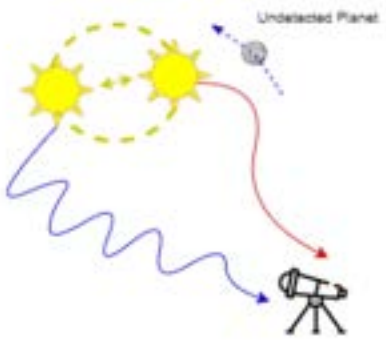

Fig. 1. Radial Velocity ("Light Curve of a Planet Transiting Its Star")

Microlensing and Direct Imaging

Direct detection is another technique in a suite of techniques used to study celestial bodies outside of the inner planetary regions, which are favored by RV and Transit measurements, as well as to find and characterize exoplanets. Within this branch of techniques, we find Microlensing and Direct Imaging.

Microlensing is the method where several images are produced in the sky and each individual image is characterized as a separate image. Through this method, the observation of the smallest and distant stars and celestial bodies are made much easier and feasible. One of the major applications, proposed by Paczynski in 1986, was the search for Dark Matter. The spectrometric lens used in microlensing are dependent upon its mass itself, hence it is able to detect the faintest of the substances at a large distance. As dark matter is thought to be made of rotation curves of spiral galaxies, which constitute as faint indicators, microlensing produces images and separates them into individuals, validating the existence of dark matter.

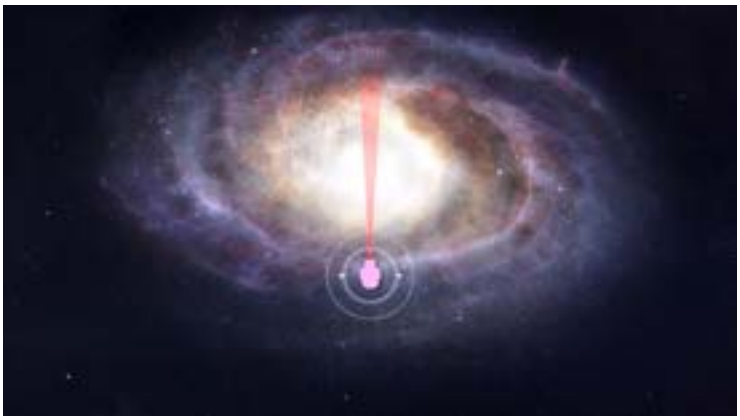

Fig. 2. Microlensing ("Microlensing - NASA Science")

Fig. 2 illustrates the phenomenon of microlensing. It is known that Light always travels in a straight line. However, if the space - time is bent, then ultimately the light starts to follow the curve. When two stars are in close proximity to each other as seen from Earth, light from the farther-off star bends as it passes around the closer star in the distorted space-time. The endeavor to find and identify exoplanets from light emitted or scattered by the planets themselves is known as "direct imaging" of a celestial body (Sturrock et al.). In this procedure, the planet and star are distinguished as two distinct points of light by using starlight suppression technique to lessen the glare from the parent star. Telescopes of large enough diameters can angularly separate the planet and star in the sky. This makes it possible to study the planet's surface and atmosphere using direct reflected light photometry as well as spectroscopy. Thus far, this technique has proven effective solely for planets resembling Jupiter located in the outer reaches of our solar system.

Transit Time

By monitoring the parent star's periodic dimming as a planet moves in front of it in our line of sight, the transit technique finds planets. The transit method is sensitive to large planets orbiting close to their small parent stars, just like the RV technique. Nonetheless, it benefits small planets that orbit close to their parent star because of their small size and shorter orbital periods, which increase the likelihood that they will appear to transit.

The planet's size and orbital period can be determined using the transit method. The orbital inclination can be determined if the transiting planet can be found using the RV method. This will allow us to determine the exoplanet's true mass. The density of the celestial body can be computed and determined using the mass from the RV and the size from the transit. Additionally, the transit method can locate habitable exoplanets of terrestrial size circling a variety of dwarf star systems in the habitable zone. This can be inferred from figure 3, as It mentions that as a planet crosses between a star and the field of view of the observation tool, the light curve is altered. Hence, the same can be seen from the figure, where the planet passes in front of the star and its duration dips below, showing an alteration of transit duration.

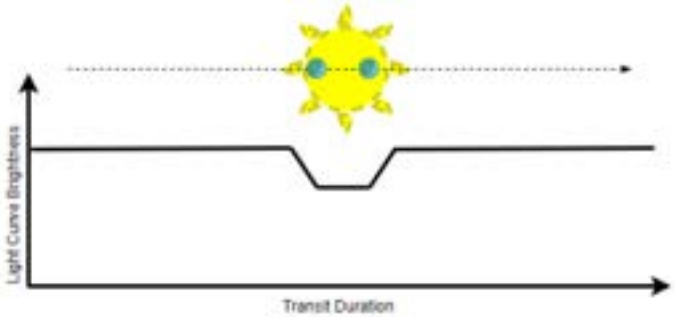

Fig. 3. Transit Time (Sturrock et al.)

Secondary Eclipse

The process of the transiting planet's photons being separated from the parent star is called a secondary eclipse. This typically occurs when the planet passes behind its host star and can be accomplished without the planet and star needing to be spatially resolved. The Secondary Eclipse method starts with the observation of an unresolved star-planet system and then subtracts an observation of the star by itself. This allows for the radiation from the celestial planet to be isolated, aiding in differentiation. However, because emission radiation is being measured, the Secondary Eclipse technique is sensitive to planet temperature. This problem can be solved by measuring atmospheric molecules using emission spectroscopy.

Learning Detection Methods

The field of Astronomy and Astrophysics have had significant developments in the recent decades. With the gradual increase of exoplanetary data as well as several ground and space-based telescopes, it can be proclaimed that this has led to an exponential rise in data collection. With the increase in demand, it is crucial to look for more methods and tools to identify such celestial bodies at a quick and efficient rate. Hence, in the field of astronomy, it can be manipulated and designed towards detecting exoplanets and serving towards identifying their habitability.

In this section, we aim to discuss the current key Machine Learning algorithms used to detect exoplanets and provide an exoplanetary discovery process with the help of the latest phenomenon.

Methodology

Machine learning can be defined as the automated self-learning system, which yields outputs from the feeded input by the user. As the usage of Machine Learning in the field of astronomy increases daily, it is important to note how big quantities of data can be transmitted and received in less time. In the context of exoplanets, data is being referred to as the features present in the light curves and signals emitted from the exoplanets and the stars nearby. Ultimately, the features include temporal patterns, transit depths, transit duration, periodicity, radial velocity variations and secondary eclipse. With several new data related to exoplanets that have been collected from such ML algorithms and models, this section explains the different ML approaches and models which have been previously used. To provide a clear and concise understanding towards the subject, the architecture of this section is divided into three procedural phases which can be seen in Figure 4; which describes 1) Light Curve Pre-processing, 2) Transit

Figure 4. Flowchart of the exoplanet discovery process

A brief description of each phase is given below:

Phase 1

This phase is also known as Light Curve Pre-processing. Upon the accumulation of light curves or light signals, it is important to filter out these data and remove any false errors present which can disrupt the findings and conclusions. Moreover, we discuss Dimensionality reduction and Bias Handling and how they can serve as a solution towards filtering the data.

Phase 2

Also known as Transit Signal Detection, this phase deals with the process of analyzing the light curves and searching for further light signals emitted by exoplanets to detect any presence of galactic events and possible habitability on celestial bodies. Moreover, this phase discusses the feature engineering procedure, which is crucial for the selection and transformation of the data on exoplanets.

Phase 3

Lastly, this phase is known as Exoplanet Identification. Once phase one and two have been successful and completed, the process of analyzing a transit like event and a particular galactic event if it has been carried out by a transiting exoplanet is performed. The aim of this phase is to confirm the presence of a habitable exoplanet.

Data Related to Exoplanets

In the previous section, we have discussed the usage of data collected from exoplanets. In this context, the data represents the features or information present in the light curves or light signals emitted by exoplanets. Ultimately, these features are then stored in the form of a dataset for the model to perform the Machine Learning Algorithms.

The different types of data present in the light curves or light signals can be inferred from the Kepler Objects of Interests (KOI) Cumulative dataset. This dataset has been formed with the help of the infamous Kepler telescope, which has immensely helped in the discovery of several exoplanets and stars. This has been defined through figure 5, which is extracted from the NASA exoplanet archive and gives the list of exoplanets and their exoplanet archive disposition. Furthermore, it consists of several features which are useful towards determining the habitability of an exoplanet.

Figure 5: KOI Table (“Kepler Objects of Interest”)

Looking at the dataset, we can observe several key features which include:

- Orbital Period - Time taken to complete an orbit around another celestial body
- Transit duration - The time an exoplanet’s shadow covers a part of a celestial body or a star
- Transit depth - The ratio between the planet and the ratio of the star squared
- Planetary radius - Distance between the planet’s center and the surface
- Stellar Effective Temperature - The amount of heat radiated towards the exoplanet per unit surface area

Using these data features, a disposition score has been set ranging from 0 to 1. The main purpose of this score is to determine if it is serving as a candidate exoplanet or a false positive candidate. If the score ranges from 0 to 0.7, it is said to be false positive. On the latter, if the score ranges from 0.8 to 1, it is confirmed as a candidate exoplanet.

Phase 1: Light Curve Pre-Processing

An observational telescope’s main function is to observe a specified region and collect data related to it and, at first, the survey of the brightest stars near Earth to search for possible exoplanets is performed by these telescopes and certain satellites. Most of the data collected is in the form of light curves or light signals, which are then implemented upon by classifiers - an algorithm which can automatically assign certain values to the data in a dataset - to monitor the intensity of the star (Jara-Maldonado et al.). The fluctuation of intensity can yield the possibility of the existence of the habitable exoplanets. This can be inferred from Figure 6, which has been adapted from the NASA Exoplanet Exploration website. The above pictorial discusses the formation of light curves. Upon the transition of the planet around the star, we can see a sudden dip in the graph, which represents the planet transiting in front of the star. The small dip further ahead depicts the transiting of the planet behind the star. Through this graph, the light curves are hence obtained.

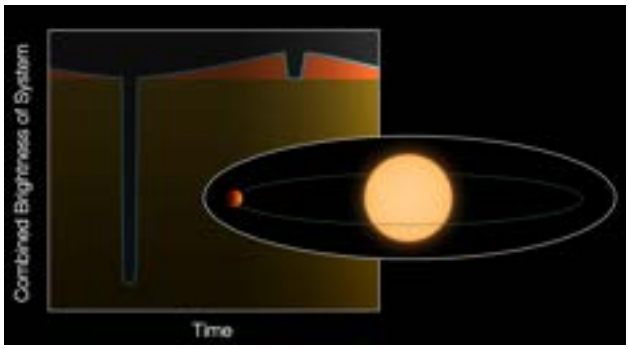

Figure 6: Light Curve ("Light Curve of a Planet Transiting Its Star")

However, through this process, the light signals can be misinterpreted for instrumental noise and furthermore, there can be vaguely small errors which can disrupt the entire dataset. For this purpose, the pre-processing of light curves is introduced into the light curves which helps in the filtering of the signal and helps in decoding. In this subsection, we aim to discuss two key methods, namely Bias Handling and Dimensionality Reduction, and how they serve towards eradicating the instrumental noise and decoding the useful information from the light signals received.

Dimensionality Reduction

Dimensionality reduction is an unsupervised machine learning technique, which helps in reducing the number of features present in the dataset. As a particular light signal can consist of several unwanted features which could disrupt the findings, the Dimensionality Reduction technique proves viable towards acting as a probable solution towards this problem (Jara-Maldonado et al.). Keeping in mind, it is extremely unlikely and expensive to consider all the features of light signals in one particular attempt. Hence, we provide a brief description of an additional technique which is related to dimensionality reduction.

a) Principal Component Analysis : This method used to convert large datasets into smaller datasets, particularly reducing the dimensions of the dataset present. In this method, the dataset is feeded, where the important and essential features are only extracted which are then trained upon. In the context of light curves, this method is key towards diversifying the variance of data as well as minimizing the computational needs required, making it both fast and efficient.

One of the key benefits of using Dimensionality Reduction is its ability to require no prior knowledge of light curves. However, it has the probability of failing to detect the key components present in the light curve, which could prove detrimental towards the findings.

Bias Handling

Bias can be defined as the favoring or unwavering of a particular idea due to several reasons that affect them personally. In machine learning, the models may be fitted with some bias from the very start of their existence, leading to several errors. Hence, it is important to handle the bias created in these algorithms, which can in turn help us get accurate results and predictions. Taking the light curves into account, it is an example of how several features are given uneven proportions of importance (Jara-Maldonado et al.). Some features are considered to be extremely crucial, while others, which are equally important, are neglected. Hence, we briefly discuss two strategies related to Bias Handling which can provide an equal balance.

a) Oversampling: The oversampling method is a process of duplicating the data or features present in the minority class. This Bias Handling method helps in maximizing the variance throughout the dataset by increasing the number of features present and giving an equal importance of each feature.

b) Undersampling: The undersampling method is a process of deleting or removing the data from the majority class. This might help in providing an equal balance, however, it also reduces the size of the dataset. Furthermore, it has the possibility of removing the crucial elements present in the majority class, which can disrupt the dataset.

Phase 2: Transit Signal Detection

As discussed in the Detection Methods section, the transit technique is undertaken by monitoring the parent star's dimming as the planet moves in front of our line of sight. Through the transit method, the planet's size and orbital period can be determined. After detecting the light curves and determining its features, it's important to undertake the process of analyzing and looking for more similar signals. Detection of more signals from one particular celestial body could be a strong indicator towards being a habitable exoplanet. To detect such signals, this phase's aim is to mainly look for the periodic transits of celestial bodies and moreover, understand the physical properties of the planet.

As previously stated, it is impossible to perform an analysis on the light curves data through Machine Learning in one computation. Hence, observing more emitted signals from celestial bodies requires a common criteria which can be applied and therefore, be used for the efficient means of discovering these curves (Susan E. Thompson and Fergal Mullally). For this particular purpose, we discuss a framework known as "feature engineering", which helps in determining and extracting features from the light curves. Moreover, it can act as a crucial booster for several machine learning algorithms. The procedure of carrying out feature engineering (Reddy Ch et al.) can be explained as below, where it is divided as 1) Feature Creation; 2) Feature Transformation; 3) Feature Extraction; 4) Feature Selection:

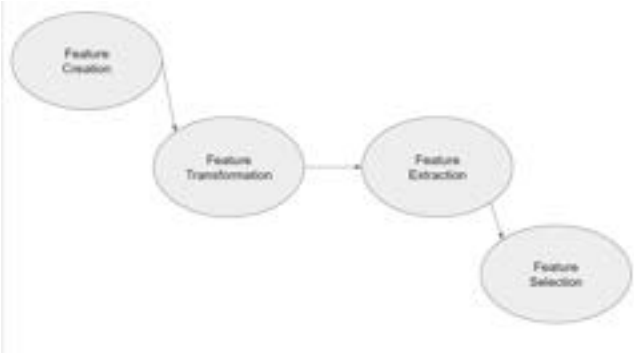

Figure 7: Flowchart of the Feature Engineering process

1) Feature Creation: Feature creation is a simple method which involves the creation of a table of new features or data from the pre-existing dataset. As previously mentioned, these features include transit depths, transit duration, periodicity, radial velocity variations and secondary eclipse.
2) Feature Transformation: Feature transformation involves the labeling of the features and is performed independently on each feature in the table.
3) Feature Extraction: The process of feature extraction involves the reduction of the dataset and extraction of the most relevant exoplanet candidates from these features. This process is mainly undertaken through Principal Component Analysis (PCA), which helps in reducing the dimensions and maximizing the variance. Upon maximizing the variance, the key features are hence identified and extracted. Through this method, it proves as an efficient way of extracting features.
4) Feature Selection: Upon extraction, the topmost features that are similar to the target features can be found out and undertaken.

To provide a clear and concrete understanding of this particular mechanism, we can look at Transit Duration variations (TDV), which refers to the changes occurring in the time for an exoplanet to cross in front of its host star. Diving into the key mechanism, this is how the feature engineering mechanism takes place:

- Detection of Celestial Bodies : This step can be linked to Feature Creation. Through gravitational interactions between several stars and their planets, the exoplanet can be discovered using the variation in transit time caused by these gravitational interactions.
- Characterization of Planetary Systems : Analyzing the TTV, the astronomers and scientists are able to lay out the architecture of the planetary systems and create a dataset with the required features.
- Verification of Candidates: TDV can be used as a criterion for the validation of exoplanet candidates. The consistency of transit durations with theoretical expectations helps in confirming the planetary nature of the observed transits.

- Stellar Activity Mitigation: Variations in stellar activity, such as starspots or magnetic cycles, can sometimes mimic the effects of exoplanets on transit durations. By analyzing TDV along with other features, astronomers can distinguish between the effects of stellar activity and true planetary signals.

By incorporating Transit Duration Variation as a feature, astronomers can improve the accuracy of exoplanet detection, refine orbital parameters, and enhance our understanding of the dynamics within planetary systems.

Phase 3: Exoplanet Identification

After the success of Phase 1 and 2 and once the transit-like event has been detected, it is necessary to determine where this event is taking place from and determine the possibility of a habitable exoplanet. Ultimately, there may also be several false positives and false errors due to instrumental errors. Hence, it is important to perform an operation called vetting, which involves the process of doing a revision of the signals and the detected event. The main purpose of vetting is to recheck and possibly remove any observable errors in the dataset.

As discussed in (Pratyush and Gangrade) the datasets need to be vetted in order to identify Kepler's object of interest (KOI). A KOI can be defined as one of the stars which were observed by the Kepler Space Telescope. These stars were proclaimed to have several habitable ecosystems near them.

Usually, the output during the Exoplanet Identification process is a yes or no answer to the inputted question. In the KOI table, several celestial bodies are given the disposition as either Candidate or False Positive. In order to determine their true habitability, we can take their stellar planetary information and conduct an analysis on the basis of them along with the features extracted from the light curves. Given the disposition score, they can be taken as the target variable whose value is between 0 and 1. Upon conducting the analysis, if the predicted score is near to 1, it can be classified as an actual candidate. However, if its value is proceeding towards 0, it can be classified as an actual false positive. Through this particular process, the habitability of an exoplanet can also be determined.

Introduction Towards New Framework

Upon discussing several detection methods in this research paper, we aim to introduce a new detection method based upon our understanding of the previously mentioned detection frameworks in this section. This concept involves the development of an autonomous model using Artificial Intelligence (AI). The main aim of this model is to integrate the new phenomenon (AI) and make the discovery of exoplanets much faster, remotely efficient, and reliable. Through this section, we aim to provide a concrete understanding of this framework by discussing its concept, methodology, benefits, risks, and its futuristic opportunities.

Concept

The autonomous model is mainly based upon incorporating Machine learning algorithms and Artificial Intelligence for it to be able to generate its own output upon its understanding. To guarantee accurate and reliable outputs, the model will be trained upon several predetermined datasets which will help in improving its accuracy level. Furthermore, the model will be publicly accessible for researchers and citizen scientists. Through this, it creates a platform for several astronomers to interact and come up with innovative solutions to detect exoplanets and further improve the model.

This model has been inspired by Zooniverse, where they include several people-powered projects and serve as a platform to enable complex research through remote locations. One of the models on this website includes the discussion of several research scientists and astronomers towards the detection of several dusty debris disks, which could enhance our discovery of the system of stars and exoplanets.

Looking at this model, our proposal involves extracting information from direct images of exoplanet candidates that have been taken by observational telescopes. To provide a clear and concrete understanding of how this exactly works, we have provided a three-step explanation below:

1. Image Extraction - There are several images of exoplanet candidates and systems present on websites such as NASA and MAST. However, it is difficult to manually detect them through images. Hence, these images can be taken and given access to the public for the sole purpose of detecting possible exoplanets, where the person can interact with the image and give possible clues towards the exoplanet's existence.

2. Public Interactivity - Upon gathering images, they can be interacted upon by the public in order to specify the location for the AI model to perform its task upon. This can be inferred from Figure 8, which has been adapted from the Website "Zooniverse", where it consists of several stars and planets; however, the main goal is to search for any dusty debris disks similar to our asteroid belt. The pointer has been marked upon by a user to check if that can serve as a potential explanation for its goal. Taking this image into consideration, the exoplanet systems and candidature images can be interacted by the user by pin-pointing the location where the AI model needs to perform its task.

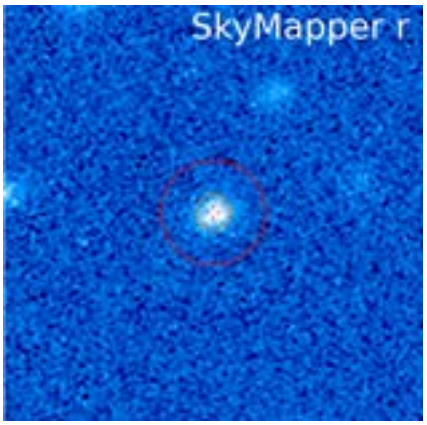

Figure 8: Image of a system of several stars (Zooniverse)

3. Implementation of ML - Pinpointing the area gives us the specific place where the model can focus upon. Through this, the model can incorporate transit photometry, where it measures the star's brightness and the periodic dips in brightness which indicates the presence of a nearby exoplanet. This step has further been explained in the subsequent sub-section.

Suggestion of the Model Architecture

To create and use this model, it requires several steps and techniques which have been used previously in this research paper. However, the methodology of implementing this model is as follows:

Figure 9 : Flowchart of the implementation of the autonomous model

The given figure depicts seven steps towards creating this model. A brief description of them is provided below:

Data Preprocessing: As discussed in the Machine Learning section of this research paper, most of the data collected by several observational telescopes and astronomical tools is in the form of light curves or light signals. However, there may be small errors and instrumental noises

present within these signals. To filter out the relevant information and data from the curves, preprocessing is required. This can be done by standardizing the data format and correcting it for any instrumental biases, ensuring a consistent output for the Machine Learning algorithms.

Feature Extraction: Upon the filtering of data from the received light curves, the new filtered data consists of several features which include temporal patterns, transit depths, durations and other key features that play a significant role in characterizing the exoplanetary signals. However, they also include features that are not useful towards performing the model. Keeping this in mind, advanced extraction techniques shall be implemented to capture the relevant information.

Machine Learning Model Architecture: From the previous 2 steps, we have obtained the filtered and relevant data that is required for this model. However, to make this model automated, it is essential to incorporate deep learning into it. Using Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), the process of analyzing the light curves and capturing the dependencies can be undertaken. Through these deep learning networks, it allows the model to process the data by itself and yield outputs, making it automated.

Transfer learning with Existing Catalogs: To make the model be able to generate its data by itself independently, transfer learning algorithms must be used on existing catalogs. Through transfer learning, knowledge is learnt and then re-used for a similar or different problem. Keeping this in mind, it allows the model to learn the general features that are associated with exoplanet signals, and improves its ability to detect potential candidates.

Real Time Monitoring and Alerts: Incorporating all the previous steps, the deployment of the model is crucial to continuously monitor incoming observational data in real-time. Implementing an alert system that notifies astronomers of potential exoplanet candidates that can enable prompt follow-up observations and validations is beneficial.

Dynamic Model Updating: With new signals and data incoming, a dynamic model updating mechanism that continuously retrains the machine learning model as new confirmed exoplanets are identified can be enabled. This ensures that the system adapts to evolving patterns and detection techniques.

Exoplanet Classification Confidence: There is always a scope for machines to make errors. Hence, integrating a confidence scoring system that provides an indication of the model's certainty in its predictions can prove to be beneficial. This allows astronomers to prioritize candidates based on the likelihood of being genuine exoplanets.

Discussion

The incorporation of several deep learning and machine learning algorithms allows this model to serve as an efficient and independent source to detect exoplanets. The key idea that differentiates this model from several others that have been used before is its automated character. Making it automated allows it to independently search and detect exoplanets without the use of any human touch. As this model performs the function of the initial stages of the

discovery process, it allows the astronomers and citizen scientists to focus on more complex tasks. These can include validating the confidence score of the model and also conducting in-depth studies.

Through its dynamic model updating mechanism, it stays updated on the latest changes and retrievals of light signals. As exoplanets are later added to the catalog, the system learns from these updates, improving its accuracy and staying current with evolving detection techniques. Moreover, its real-time monitoring system enables astronomers to receive immediate notification of the potential exoplanet candidates.

Lastly, the model can serve as an educational outreach tool, where several young citizen scientists and youth researchers can join hands from anywhere around the world, and contribute towards finding the next plausible Earth. Also, the usage of Machine learning algorithms and deep learning methods contribute towards the advancement of new technological applications in astrophysics. This technological progress not only benefits exoplanet research but also lays the foundation for future innovations in data analysis for various astronomical phenomena, as Neil Armstrong once said, “One small step for man, one giant leap for mankind”.

While it serves as a promising solution towards various problems, it is crucial to discuss its risks and challenges that can hinder our progress towards discovering exoplanets.

- False Positives : Machine learning models can wrongly assume candidate exoplanets to be false positives and vice versa. Hence, overreliance on such models can lead to huge errors in the dataset as well as hinder our progress in discovering exoplanets.
- Diverse Signal Characteristics : The diversity of astrophysical signals, including instrumental noise, stellar variability, and other transient phenomena, poses a challenge for machine learning algorithms. Developing a model robust enough to distinguish between various signal types while being sensitive to genuine exoplanetary signatures is a complex task.
- Incomplete Training Data: The training of machine learning models relies on existing knowledge and confirmed exoplanets. However, our understanding of exoplanets is still evolving, and there may be unknown classes or characteristics not well-represented in training data, leading to potential blind spots.
- Computational Requirements: Implementing a real-time, machine learning-driven system demands substantial computational resources. Ensuring scalability, reliability, and accessibility of the platform may pose challenges, especially for smaller observatories or institutions with limited resources.

Remembering the positives and negatives of this model, it is crucial to understand that the model is not robust enough to be broadly applicable. Even if the model works well in a development environment, it is prone to make mistakes on unseen data. To mitigate these risks, a careful approach to development, validation, and integration is crucial. Continuous collaboration between machine learning experts, astronomers, and citizen scientists is essential for addressing challenges and refining the model over time. Additionally, transparent communication about the

system's capabilities and limitations is vital for building trust within the scientific community and the wider public.

Conclusion

Throughout this research paper, we have discussed several key terms that affect the habitability of an exoplanet. Furthermore, we have provided a survey on the conventional methods as well as the machine learning methods towards detecting exoplanets. Lastly, we propose a concept of building an autonomous model which integrates the likes of Artificial Intelligence, Machine learning, and is based upon making it publicly accessible, data-rich, and remotely efficient. Through this model, it provides a platform for several scientists and astronomers to interact with each other and come up with innovative solutions to tackle various problems in the field of astronomy.

Our approach consists of extracting several images from sources like NASA and MAST which can be interacted upon by the public. The public can then specify a particular location on the image where the autonomous model must perform its function upon. Later on, we discuss how the model can detect the presence of an exoplanet using light curves and extracting data from the points pinned on the images by the user. Finally, an exoplanet classification score can be set in order to determine if it serves as a candidate exoplanet or if it is a false positive.

We have discussed several terminologies and methods throughout the paper. However, the key takeaway that we would like the reader to remember is the fast evolving pace of Machine learning in the field of astronomy. As new methods evolve which are more advanced and efficient than the current methods, it is crucial to understand these methods and further enhance our understanding towards exoplanets. Lastly, the usage of Artificial Intelligence cannot be understated, as it proves to be the latest phenomenon. With the use of new and upcoming revolutionary telescopes, our knowledge of space in its entirety will be further enhanced and open up worlds to different theoretical dimensions.

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Studying Changes in Lung Compliance as a Model of EVALI Lungs by Sidharth Rane

Abstract

The respiratory system is a complex network of organs responsible for gas exchange in the human body. The recent rise of the popularity of electronic cigarettes and vapes has led to a new type of lung injury known as E-cigarette or Vaping Product Use-Associated Lung Injury (EVALI). This paper investigates the relationship between lung compliance and pressure, particularly in lungs affected by EVALI. The study uses mathematical modeling and comprehensive research to explore how compliance and pressure interact in EVALI-infected lungs. The results aim to provide insights into the effects of compliance and pressure in lungs impacted by EVALI.

Introduction

The respiratory system is essential for sustaining human life and is extremely complex. The system comprises networks responsible for gas exchange between the body and its environment. The system contains seven major organs that work together to deliver oxygen to the bloodstream. The lungs play a central role in the human respiratory system by facilitating the exchange of oxygen and carbon dioxide through complex and intricate processes (Clevland Clinic, 2020). Lung physiology encompasses many mechanisms all working together to oxygenate the human bloodstream. The oxygen that is absorbed into the bloodstream, is crucial for cellular respiration and the overall metabolic function of the human body (Britannica, 2022).

Amidst the rise in the use of e-cigarettes and other electronic vaping devices throughout the world in the last few decades, many users are now experiencing what is known as EVALI (E-cigarette or vaping product use associated lung injury) (Yale Medicine, 2022). EVALI represents a group of symptoms and lung injuries caused by the use of e-cigarettes or vaping products, which is now causing a modern challenge, and public health authorities and medical professionals are starting to understand EVALI more (American Lung Association, 2023). The short-term and long-term effects of EVALI are not completely understood, however, medical professionals do know that it starts in the alveoli in the lung.

The alveoli are minuscule air sacs located in the lungs, specifically at the ends of the bronchioles (small airways). The alveoli are the primary sites of gas exchange in the respiratory system. Each alveol is around 200 micrometers or 0.02 centimeters in diameter, and they are shaped similar to a grape (Biology LibreTexts, 2018) the alveoli are comprised of epithelial cells, which are made up of two distinct types of pneumocytes. Type 1 pneumocytes facilitate gas exchange in the respiratory system. Type 2 pneumocytes produce surfactant in each alveol (Stanton and Koeppen, 2018). Each alveoli is surrounded by various capillaries which are a network that allows for the exchange of oxygen and carbon dioxide between the outside environment and the bloodstream. The alveoli's main function is to facilitate the exchange of oxygen and carbon dioxide between the lungs and the bloodstream. The process works when oxygen is inhaled from the air and the inhaled air diffuses across the thin walls of the alveoli and

then into the bloodstream, where it then attaches to red blood cells. The product of this is carbon dioxide, that is exhaled from the body during respiration (Biga, 2019). In type 2 pneumocytes, there is a substance called surfactant that is a mixture of the two macromolecules: proteins and lipids. The surfactant is composed of 4 major components: dipalmitoylphosphatidylcholine, phospholipids, surfactant proteins, and neutral lipids, (Griese, 1999). Surfactants' role in the alveoli is to reduce the surface tension within the alveoli, which prevents the alveoli from collapsing during respiration. Furthermore, surfactant also helps maintain the structural integrity of the alveoli and allows for their expansion while inhaling air, without surfactant the lungs would suffer from atelectasis, which is the collapse of alveoli (Scurch, 2009).

Lung compliance refers to the ability of the lung tissue to stretch and expand in response to pressure. This phenomenon is crucial for proper lung function as it determines the ease with which the lungs can fill with air during inhalation. Compliance is influenced by the elasticity of the lung tissue and the surface tension within the alveoli (Biga, 2019). The formula for lung compliance used in this paper is $P_F = (C * \Delta V) + P_I$. The variable C represents compliance, while the P represents the initial pressure and the final pressure, and ΔV represents the volume change. High lung compliance indicates that the lungs can expand easily with little pressure, while low compliance means that more pressure is needed to achieve the same volume change (Varadhan, 2022). Lung compliance is a critical factor in the functioning of alveoli throughout the human lung. Since the alveoli's main function is to facilitate gas exchange, and therefore the air sacs need to be able to expand and contract efficiently. Compliance is influenced by the structural properties of the alveoli, including the presence of surfactant, which reduces surface tension and presents alveolar collapse (Landry, 2023).

The epidemiology of EVALI reveals a demographic pattern predominantly affecting young adults and adolescents, who are more likely to use an e-cigarette or vaping device rather than a standard cigarette. While the exact cause is currently unknown, EVALI cases have been linked to Vitamin E acetate, a prevalent compound used in vaping products (Belok, 2020) Furthermore, it is also understood that EVALI causes lung inflammation and other inflammatory reactions in the respiratory system. Finally, the regulations surrounding these devices are very weak, and accessibility to the devices is high, therefore making EVALI a very dangerous public health concern (Yale Medicine, 2022).

The current understanding of EVALI suggests that multiple factors contribute to lung injury and respiratory compromise. Inhaling aerosolized substances from vaping products may initiate a cascade of inflammatory responses within the lung microenvironment (Yale Medicine, 2022). EVALI can cause, and in many cases lead, to acute respiratory distress, pneumonia-like symptoms, and, in extreme cases, respiratory failure. The pathophysiology of EVALI remains something that is under current investigation, as the mechanisms and interventions to prevent and treat EVALI will be critical and help individuals facing a critical threat to their respiratory health.

This study aims to investigate the relationship between compliance and lung volume, and their alterations in the context of e-cigarette or other vape device use, specifically considering the presence of vitamin E acetate. The intricate relationship exhibited between these pressure

dynamics in a healthy lung will be explored to highlight their pivotal role in sustaining respiratory function and facilitating efficient gas exchange. Using comprehensive modeling software along with several research studies, this investigation combines these factors to identify how conditions such as EVALI truly affect lung volume. This investigation strives to contribute to the body of knowledge surrounding respiratory health, providing insights into the physiological consequences of e-cigarette use, and informing strategists to mitigate the risks.

Methods

To investigate the relationship between lung compliance and the pressure needed to expand the lungs, and how this relationship relates to EVALI , this study employed a specific methodology. No human patients were involved in the data collection process. The initial step was to use a formula for lung compliance, defined as the change in lung volume per unit change in pressure ($C = \Delta V/\Delta P$). The study utilized three different compliance values: a normal or control value: 200 mL/cmH_2O, a value representative of EVALI-affected lungs 75 mL/cmH_2O, and a value lower than the EVALI value which represented fibrotic lungs: 35 mL/cmH_2O. Additionally, a range of lung volumes was determined based on the standard range for males, measured in liters. These values were then used to identify trends by running computational simulations. The simulation results were subsequently imported into Microsoft Excel, where four graphs were generated to illustrate the findings. This approach allowed for a comprehensive analysis of the relationship between lung compliance, pressure, and EVALI, providing valuable insights into the underlying mechanisms.

Results and Discussion

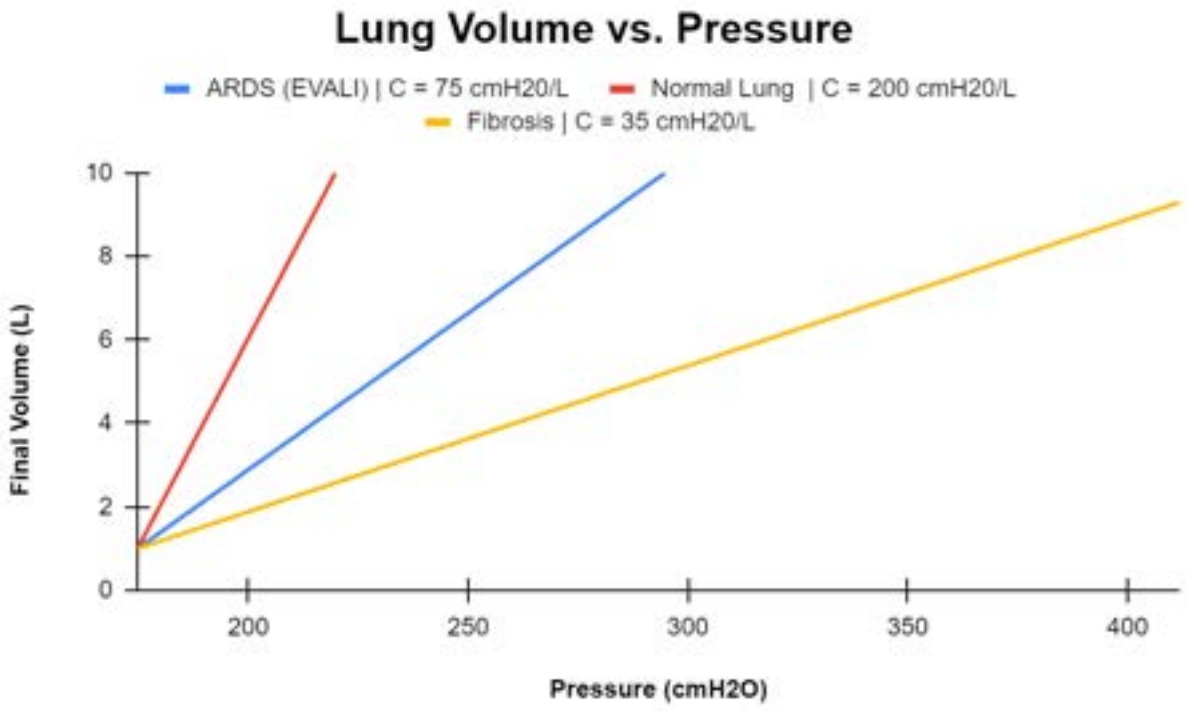

Figure 1: This figure illustrates the final volume of the lung, as the pressure increases.

Figure 1 illustrates all three compliance levels. It caps the final capacity of the lung volume at 10 liters since that is about 40% over the maximum capacity of the normal human lung. The popularity of vaping has increased during the last two decades in the United States and in the world. The increase in vaping may have occurred because it has become a more popular substitute for traditional forms of smoking. Due to the rapid rise of vaping there are alarming health concerns, particularly related to lung health. Among the various substances used in e-cigarettes and vaping products, Vitamin E acetate has emerged as a critical factor in vaping-associated lung injuries. The discussion explores the physiological impact of Vitamin E acetate on the lungs, its role in real-world vaping applications, and the broader implications for public health and regulatory measures.

Vitamin E acetate affects the hundreds of millions of alveoli in the lungs that are responsible for lung gas exchange. Vitamin E acetate located in the alveoli can cause similar effects in the lungs as acute respiratory disorder syndrome (ARDS). ARDS occurs when the lungs are unable to provide sufficient oxygen to the body's organs and tissues. ARDS also causes an inflammatory response, leading to a decrease in the alveoli and lung function. When looking at the compliance of the lungs, it is the measurement of how the lungs can expand and retract. It measures how easily the lungs can expand and also contract to their original shape, a vital part of the lung's structure and function. If the lungs are too stiff or too stretchy, there will be insufficient amounts of gas exchange therefore that creates a lower compliance value in the lungs. The lower compliance values that are in the lungs, over time will cause the lungs to use more pressure to

expand to their full capacity (final volume) in comparison to the normal lung. The increase in sustained pressure will over time cause the lungs to encounter additional stress that increases over time. Increased pressure on the lungs leads to overall deterioration of the respiratory system. As shown in Figure 1, as the compliance increases the amount of pressure to reach the same amount of volume in the lungs can be seen to decrease. On average, a pair of healthy lungs can contain between 3 and 6 liters of air at their maximum volume. In order to reach the maximum capacity of a healthy lung, a lung with a compliance level of 200 will only have to endure 200 cmH20 of forces. However, as the compliance further decreases in the lungs, for example, to 75 it can require the lungs to endure about 248 cmH20, a 25% increase. Decreasing the compliance to further a fibrotic level of around 35 would lead the pressure in order to reach a maximum capacity of the lungs to be around 325 which is a 62.5% increase in the amount of pressure to reach the final lung volume.

Conclusion

The main takeaway from the study is that lung compliance and lung volume are closely related. Vaping is clearly dangerous, but the severity and the issues and consequences that arise from consistently vaping from a young age can affect more than just lung volume. The most significant finding is that as compliance decreases, the pressure required to inflate the lungs increases. Over time, this can severely decrease lung capacity and the lungs' ability to transport oxygen for the human body.

In the broader context, the research further demonstrates that EVALI is very harmuful to the lung. The long-term effects of vaping are not yet fully understood, but in the next decade, more will be known about how vaping and the chemicals inhaled from it truly affect the lungs and how severe and irreversible the damage can be.

The next steps in this research would be to compare individuals who use vapes with those who do not, to understand how daily life is affected by vaping. This comparison would help in understanding how pressure to expand the lungs affects both the macro parts of the respiratory system and the micro parts, such as the individual alveoli and surfactant.

However, the study has some limitations. The sample size was small, and there was a generalization that there is no specific compliance value for EVALI, so Acute Respiratory Distress Syndrome (ARDS) was used instead. Additionally, no actual patient data was used; the study relied on a model, which is a good predictor of trends but may not accurately represent real-life scenarios. Anomalies and other circumstances may alter these results.

Overall, this research underscores the significant health risks associated with vaping and highlights the need for further studies to understand its full impact on lung health.

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Coral Restoration Methods in Response to Future Climate Issues by DaJeong Won

Abstract

The changing ocean climate has various implications for the fate of coral reefs and its neighboring ecosystems. Global ocean surface temperatures have increased since the 20th century and consistently risen since the 1950's. Further, the rapid increase in carbon dioxide emissions have caused the ocean to be more acidic as carbon dioxide gets dissolved by the ocean. Many of these drastic changes have detrimental effects on corals as it affects the formulation of corals' calcium carbonate skeleton. Additionally, rising ocean temperatures have caused more bleaching events. Due to the loss in corals, the biodiversity of fish has declined by 63% while the abundance of fish has decreased by 60%. (Natural History Museum). There have been many efforts to increase the declining population of these species. However, it is vital to understand how to adapt coral restoration methods to be resistant to future climate issues. Amongst the many methods utilized for coral restoration methods, ones that focus on improving the species' resilience have shown promise.

Key Terms: coral reef, climate change, ocean acidification, restoration

Introduction

Due to climate change, the global ocean's surface temperature has shown a mean warming trend of 0.062 ± 0.013°C per decade over the last 120 years. (Garcia-Soto, Cheng, Caesar, Schmidtko, et. al, 2021). The top 700 meters (2,300 feet) have warmed about 1.5°F since 1901. (Woods Hole Oceanographic Institution). As the interior ocean temperature continues to rise, ice sheets and permafrost melt, causing the hydrological, atmospheric, and oceanic circulation to be altered. This in turn causes longer and more powerful typhoons and flooding periods. There are various other factors to consider when considering the effects on climate change and the ocean. For instance, global surface pH has declined by approximately 0.1 pH units since the industrial revolution. (Garcia-Soto, Cheng, Caesar, Schmidtko, et. al, 2021).This decline in pH is contributed to carbon dioxide emissions altering the ocean chemistry as more CO2 is absorbed into the ocean. Therefore, creatures that create calcium carbonate shells such as shellfish, corals, and oysters, have a hard time forming their calcium carbonate skeletons due to CO2. (Garcia-Soto, Cheng, Caesar, Schmidtko, et. al, 2021).

Corals are critical ecologically, culturally, and economically. Reefs serve as shelter, protection, and breeding grounds for 25% of all marine species despite only making up 0.1% of the entire sea. Moreover, the total economic value of coral services is 3.4 billion dollars due to fisheries, tourism, and coastal protection, and 1 billion people are impacted directly or indirectly by coral reefs. Further, coral reefs provide natural shore protection, dissipating around 97% of incident wave energy by frictional dissipation. (Goreau et. al, 2017). Thus, they provide flood benefits of $1.8 billion dollars in averted damages to property in the U.S.. (NOAA, Tables 1-3).

Corals consist of tiny polyps that secrete a layer of calcium carbonate to create a rocky exterior. As coral larvae or fragmented parts of the coral attach themselves to hard surfaces

nearby the coral, the singular coral develops into a reef. Corals have a mutual relationship with Zooxanthellae algae, which is a type of algae that lives within the tissues of the corals and provide oxygen which helps corals remove waste. The zooxanthellae also provide corals with glucose, glycerol, and amino acids, which the corals use to make protein, fat, carbohydrates, and calcium carbonate. (NOAA, paras. 1-2).

When stressed, coral polyps expel Zooxanthellae algae within them, giving the corals a white appearance which is otherwise known as coral bleaching. Thus, reefs become much more vulnerable to diseases such as white syndrome when Zooxanthellae algae is expelled.Coral reefs have declined by over half since the 1950's due to the effects of climate change and overfishing. (Ashworth, 2021). Additionally, 14% of the world's coral has been lost from 2009 to 2018. Therefore, there have been countless efforts to resurge the declining population of corals through restoration methods such as removing invasive algae, coral gardening, substrate manipulation, substrate stabilization, larval propagation, direct transplantation, substratum enhancement with electricity, and cryopreservation. All of these ways have their intended purposes whether it is trying to improve coral diversity in an area, striving to repopulate a patch of the ocean seas with corals, or trying to make them more resilient against climate change.

Dynamic systems such as coral reefs have an innate capability for natural recovery, however, the frequency, intensity and severity of mass coral bleaching and extreme weather events is increasing, diminishing the time and capacity for recovery between catastrophic events. A lack of natural recruitment and insufficient time for recovery between disturbing events causes natural recovery to be unlikely, or impossible in many locations. Combating habitat loss on multiple levels is likely to be the fundamental issue for ecologists which has led to an increasing interest in methods that can boost the resilience of reefs, or aid in the preservation and restoration of coral reef structure and function. (Boström-Einarsson et al., 2020).

Table 1: Restoration Method Definitions

Restoration Method	**Definition**
Removing Invasive Algae	Removing invasive algae is a restoration method in which macroalgae is eradicated or controlled from the corals.
Coral Gardening	Coral gardening is a restoration method in which corals are grown in nurseries through asexual reproduction until they are mature enough to be planted back on the reef.
Substrate Manipulation	Substrate manipulation is a method where artificial structures with planted corals are planted among the reef.

Substrate Stabilization	Substrate stabilization is a method where substrate such as concrete to minimize fracture or movement.
Larval Propagation	Larval propagation is a method where larvae are reared until they are ready to be attached to an artificial structure or on top of a reef.
Direct Transplantation	Direct transplantation is a method where grown corals are transported and replanted from one place to another.
Substratum Enhancement with Electricity	Substratum enhancement is where electrical currents are used to mimic the chemical composition of a coral skeleton.
Cryopreservation	Cryopreservation is a method where coral larvae or adult colonies are frozen in liquid nitrogen.

Global Ocean Warming

Sea surface temperature (SST) across much of the tropics has increased by 0.4° to 1°C since the mid-1970s. (Canten, Cohen, Karnauskas, et. al, 2010). Due to human activities, greenhouse gas emissions have disrupted the natural energy flow causing an energy imbalance in the Earth's climate system. More than 90% of the excess heat is accumulated within the global oceans. (Garcia-Soto, Cheng, Caesar, Schmidtko, et. al, 2021). There has been substantial warming in the Southern Ocean (70°S~40°S) and Atlantic Ocean (40°S~50°N) with weaker warming throughout the Pacific and Indian Oceans (30°S~60°N). (Cheng et. al, 2017).

Global ocean warming has contributed to an influx of thermal stress which can cause coral bleaching and a rise in infectious diseases. (NOAA). White syndrome is a disease that destroys coral tissue and seems to be significantly impacted by the warm temperature irregularities. Corals are more likely to be infected with the white syndrome in tropical waters since that is where temperature anomalies occur most (Bruno, Selig, Casey, et. al, 2007). The most common symptoms of the white syndrome are often characterized by a white band of tissue or a recently exposed skeleton that infects the colony as the disease progresses. (Willis, Page, et. al, 2004). Unlike coral bleaching, the white syndrome completely kills the coral as its tissue is destroyed.

In a study done at the Great Barrier Reef (GBR), forty - eight corals were monitored over the span of 6 years. Reef-specific weekly sea surface temperature anomalies (WSSTAs; the frequency of deviations ≥ 1 °C) were derived from a satellite sea surface temperature (SST) database. (Bruno, Selig, Casey, et. al, 2007). The white syndrome has been present in the GBR

since at least the beginning of systemic disease monitoring in 1998, but its frequency increased 20-fold in 2002 which was the year after the region experienced its second warmest summer in the 20-year satellite record, with 58% of reefs having weekly anomalies of 1°C or higher. (Willis, Page, et. al, 2004). During cooler months, there is an increased accumulation of coral-tissue biomass and greater densities of zooxanthellae which are crucial processes that corals go through to protect themselves from future stressors. However, these processes are compromised by longer warm periods throughout the seasons which can make corals susceptible to disease and facilitate rapid pathogen growth. (Bruno, Selig, Casey, et. al, 2007).

There have been radical steps taken in the scientific community to find a solution that could create resistant corals that would be able to withstand future atrocities of climate change. For instance, rearing interspecific hybrids in the laboratory and subjecting these hybrids to predicted near future conditions such as slightly elevated temperature and CO2 levels can be used to identify the genotypes that are fittest in those environments. As a result, these genotypes can be used for further breeding. (Oppen, et. al, 2015).

Research to assess the feasibility of assisted evolution of corals in the face of ocean warming is accelerating. However, frameworks for practical application of this research are lacking. (Madeleine et al., 2015). Furthermore, the process of assisted evolution is costly, especially if the restoration efforts were to be scaled up. (Madeleine et al., 2015). Regardless, there are still methods to reduce total costs such as decreasing husbandry times and reducing the costs with monitoring by incorporating locals and tourists. (Sinclair et al., 2021).

Another method that has been gaining attraction is translocation of adult corals from a warm reef to a cooler reef or seeding the cool reef with recruits of the warmer reef could be strategies to accelerate enhancement of upper thermal tolerance limits. (Oppen, et. al, 2015). However, the scale of such translocations would be challenging in terms of cost and the need for extensive international coordination. Further, it is possible that Gulf populations have diverged to the point where they are unable to survive seasonal extremes at the transplant location or are no longer able to interbreed with other Indo-Pacific conspecifics. (Oppen, et. al, 2015).

Global warming is an issue that will unfortunately continue to prevail, causing the corals to not have enough time to recover naturally. However, restoration methods for improving the resilience of reefs are not as developed or practiced as other common restoration methods because it calls for much resources and time. Regardless, the potential of growing resilient reefs should not be overlooked and more research should be done.

Ocean acidification

The CO2 levels in the atmosphere spiked for the last 200 years since the industrial revolution. The ocean, which absorbs approximately 30 percent of the world's CO2 concentration, has been increasing. Through a series of chemical reactions, the increase of CO2 causes a growth of hydrogen ions, resulting in the seawater to become more acidic and causing carbonate ions to be less abundant. (NOAA)

As a consequence of ocean acidification (OA), the ability of marine calcifiers to produce calcium carbonate ($CaCO_3$) and their rate of $CaCO_3$ production decreases. In order for a coral reef to grow, it must produce calcium carbonate at a rate that is faster than the rate of the reef being eroded. Ocean acidification slows the rate at which coral reefs can generate calcium carbonate, thus slowing the growth of coral skeletons. (NOAA) This causes the resiliency of corals to inevitably decrease, making them more vulnerable to storms and harmful macroalgae. (Mollica et. al, 2017). For example, researchers used a growth model which showed that ocean acidification directly and negatively affected the skeletal density which could decline by up to 20.3% over the 21st century solely due to ocean acidification. (Mollica et. al, 2017).

However, ocean acidification is not only affecting the resilience of coral reefs but also contributing to the coral bleaching events as well. For instance, in a study done at the Florida Keys, researchers discovered that high CO_2 dosing led to 40-50% bleaching for the crustose coralline algae (CCA) and Acropora after 8 weeks of experimentation. Crustose coralline algae is a type of hard algae that contains calcium carbonate, similar to corals. At the highest CO_2 dosing under warm conditions, productivity of CCA was 160% reduced relative to the warm control conditions as the daily rates of respiration far exceeded the daily rates of photosynthesis. (Anthony et. al, 2011). Results of a recent study using the same experimental conditions (A. Crawley, S.D.,and K.R.N.A., unpublished data) showed that high CO_2 and/or lowered pH disrupt the photoprotective mechanisms of coral symbionts or algal chloroplasts by lowering rates of photorespiration and the capacity for thermal dissipation.

In order to control the harmful macroalgae that could swarm and suffocate the corals while they are in a vulnerable state due to ocean acidification, high herbivore grazing and low nutrients have the potential to play a critical role in maintaining coral resilience while CO_2 concentrations are stabilized. (Anthony et. al, 2011). With more macroalgae being consumed by grazers, there is a lower probability that the algae will decompose and release more CO_2 in the body of water.

Furthermore, substratum enhancement with electricity, which is a relatively newer coral restoration method, could be useful in helping corals with the decline of skeletal density. The technique, substratum enhancement with electricity, otherwise known as Biorock is essentially a structure made up of metal rods that has direct current flowing through it, producing a white exterior of limestone or calcium carbonate. This method has been known to repair damaged corals.

For instance, corals growing on the Biorock reef had 50 times (5000%) higher coral survival than the adjacent natural coral reef after the 1998 coral bleaching event. (Goreau et. al, 2017). Additionally, a Biorock installation done in Indonesia, Biorock structures enabled new beach growth and within a year a gap that has been underneath a structure has been filled in from the sand rising. However, a nearby area without Biorock was completely destroyed.

While methods such as Biorock sound promising, multiple experiments have failed to describe similar positive effects of exposing coral fragments to an electrical field. For example, A. pulchra and A. yongei coral fragments exposed to similar strength electrical currents as those

described by previous researchers grew slower than control colonies. Similarly, another researcher described negative effects on growth of one species of coral (A. yongei) but positive effects on another (A. pulchra) growing on a cathode, suggesting that results may vary even between congeneric coral species. The disagreement between studies prohibits clear conclusions about the mineral accretions method. (Boström-Einarsson et al., 2020).

Dissolved Oxygen Concentration

Dissolved oxygen concentration, like its name, is a measure of how much oxygen is dissolved in water and is the amount of oxygen that is available to aquatic life. There have been various factors as to why dissolved oxygen concentration is decreasing. One is due to the rising temperatures; since dissolved oxygen concentration (DOC) is inversely related to temperature, DOC has decreased over time. Another is due to an excess amount of nutrients from fertilizers and pesticides that enter the waterways which causes an increase of algal blooms which decompose, costing oxygen in the process. The lack of DOC has caused extreme hypoxic conditions throughout bodies of water leading to what is known as "dead zones." (USGS, 2018).

For example, in September 2010, coral reefs in Almirante Bay, Bocas del Toro Province, were turning white. However, unlike bleaching events, these corals also had thick mats of bacterial slime, dead bodies of crabs, sea urchins, and sponges scattered on the ocean floor. Furthermore, there was a clear line where above it, the corals still looked healthy while below, they were dying. (Altieri et al., 2017). Unlike ocean warming and acidification which are among the most recognized global threats to coral reefs, dead zones caused by a lack of dissolved oxygen concentration are more localized. (Altieri et al., 2017).

As a result, while dead zones are slowly gaining recognition, the consequences of hypoxia and dead zones are not as included in scientific conversation. For instance, in 2016, and dead zones were only mentioned in 0.2% of the abstracts from the 2016 International Coral Reef Symposium. (Alteri et. al, 2017).

However, monitoring protocols for coral reefs typically do not call for measurements of oxygen concentrations, making it difficult to identify hypoxia-driven mortality after it has occurred. (Alteri et. al, 2017). Furthermore, scientific research on dead zones is dominated by investigators from temperate zone countries or other countries with strong research investment. For example, "37% of the 43 known tropical dead zones were first described by research teams led by principal investigators based in the United States or Europe, and another 28% were described by teams with principal investigators from Brazil, India, or China–countries with advanced research infrastructure." (Alteri et. al, 2017).

Due to the lack of research, there have not been many solutions for the problem of dissolved oxygen concentration. Regardless, as dead zones are often caused by human activity, ensuring that agricultural runoff does not end up in waterways is one of the main ways to decrease the chance of harming the waters. Therefore, there are many mitigation steps that one could take to reduce the chance of a dead zone.

Discussion

Global temperature is predicted to increase for several more decades even in a zero-carbon emission scenario. (Boström-Einarsson et al., 2020). Therefore, it is vital for corals to be resilient to future bleaching events or extreme weather cases. In order to maximize survivability, adaptation is necessary. Assisted evolution and migration are some ways that could improve the resistance of corals against future climate change. However, it is necessary to consider the allotted time and resources a community has to restore declining corals. Many coastal regions do not have the means of translocating an adult colony across long distances. Thus, alternative methods such as increasing the number of herbivore grazers by introducing more sea urchins and oysters could be more cost effective.

As a fundamental baseline, mitigation efforts to reduce the amount of agricultural run off, pollution, and overfishing are necessary steps of actions that should be taken. Moreover, in the future, long lasting monitoring systems that survey an area are necessary as many researchers only survey the area they research in for around a year which could cause an inflation in researchers' data. The importance of monitoring has been shown throughout various experiments. For instance, researchers would not have been able to notice the dead zone in Almirante Bay if they did not have an active international research station near one of the most impacted reefs. (Altieri et al., 2017). Incorporating tourists and locals in long term monitoring could be a cost effective method. (Sinclair et al., 2021). Overall, there is still a great demand for further research in newly developed restoration methods such as Biorock and assisted evolution. With an understanding of the dire conditions of corals, opening up to different restoration methods is crucial.

Conclusion

In conclusion, there is still much uncertainty as to how coral restoration methods should proceed due to the uncertainty of human activities. Although there are places that may be affected with more global ocean warming than another area which may be impacted more by dead zones, it is necessary to consider that all of these issues coincide and overlap with one another. Often, the cause of one is the result of the other; there is no "one size fits all" restoration method for each issue. However, an element of adaptation must be implemented in all future restoration efforts.

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Navigating the Ethical Landscape of Gene Editing for Breast Cancer Treatment By Emily Quach

Abstract

Breast cancer affects 1 in 27 individuals globally, and existing treatments are often insufficient. CRISPR is emerging as a potential solution for breast cancer, but the ethical limitations are underexplored. Therefore, this paper examines the ethical considerations of using CRISPR to treat breast cancer. Through the lens of financial, ethical, legal, emotional, and physical responsibility, it covers the nuance that accompanies CRISPR's application into healthcare. While breast cancer imposes a heavy burden on those affected, ethical limitations of CRISPR are equally important to consider. To analyze the ethical values of CRISPR, primary sources and ethical papers and reviews were evaluated. Despite its promise, CRISPR faces significant ethical challenges, including genetic privacy, equity, and long-term effects. Public engagement and ongoing research are crucial for its potential in breast cancer treatment, but addressing these ethical issues is essential for its responsible and equitable use in healthcare.

Introduction

In 2022, 2.3 million patients were diagnosed with breast cancer, globally (World Health Organization). Although not everyone gets breast cancer in their lifetime, the probability that someone you know will get it is quite high. Therefore, the impacts of breast cancer extend beyond those who are directly diagnosed. One must consider living the rest of their life with a part of themselves missing. Would permitting such a procedure that alters your natural genetic makeup seem moral? Is it ever justifiable to undergo this? Imagine facing cancer, and the potential life-saving impact gene editing could have.

There are a lot of open questions about how CRISPR could impact future generations. In fact, genetic technology has begun to rapidly emerge in the past few decades, specifically CRISPR. Technologies such as these are used to model human disease and understand gene functions. CRISPR, clustered regularly interspaced palindromic repeats, is one specific gene-editing tool that has become revolutionary in the world of science (Asmamaw and Zawdie). This technology works by creating breaks in double-stranded DNA and uses Cas-9 proteins to carry out the intended mutations in the targeted region. In other words, CRISPR can be thought of as scissors, cutting away a portion of DNA, in order to have it replaced or repaired. The discovery of such technology has resulted in advancements within genetics, prompting researchers to curate a multitude of new methods of application. With additional research and experimentation, the technology can have the capacity to do wonders, for instance treating various types of diseases or enhancing traits in organisms. In the past year, the first gene-based therapy treatment, used to treat sickle cell disease for patients with recurrent vaso-occlusive crises, was approved by the U.S. Food and Drug Association (FDA). This treatment modifies blood stem cells to facilitate higher levels of fetal hemoglobin, which will prevent the sickling of red blood cells.

In 1987, Yoshizumi Ishino started the building block for CRISPR when he unintentionally duplicated a set of repeating sequences, which consisted of spacer sequences, when working with *Escherichia coli* DNA. In the following years, scientists began to notice these spacer sequences, which play a significant role in helping Cas proteins reach the targeted location. CRISPR was officially created in 2012 by Emmanuelle Charpentier and Jennifer Doudna (Farhud and Zarif-Yeganeh). Together, they further advanced the technology by investing into its development and applying it to the biotechnology industry, where it has continued to grow and expand.

With the endless possibilities that come with CRISPR follow a plethora of ethical concerns and legislative restrictions. Bioethical concerns have surfaced because of this new technology within moral, legal, agricultural, environmental, and medicinal regards. Studies that have recorded the outcomes of embryos altered by CRISPR, have not been able to predict the effects, regardless of whether they were expected or non-targeted (Ayanoğlu et al.). The mutations, regardless of what they may be, now have the potential to be passed down to future generations. If these mutations happen to be harmful to human health, and are being inherited in the following generations, society will surge with demand for medical attention, consequently affecting the economy and quality of life. Inequalities are also a large concern: this technology would only be accessible to those who have the financial privilege to afford it, therefore leading to social inequalities along with physical bodily advantages of recipients. Referring back to the recently approved treatment for sickle cell disease, one treatment is reported to cost approximately $2.2 million. The unimaginable cost for this treatment places it out of reach for a large majority of Americans. Concerns around the ethics of using CRISPR limit its involvement in our current society. Because we are uncertain about a multitude of its effects on organisms and on our world's construct, we are unable to rapidly advance research in this field. Despite its potential to cure diseases and revolutionize various fields, CRISPR/Cas-9 faces ethical concerns, legislative restrictions, and uncertainties regarding its effects on organisms and society, limiting its widespread application.

Some countries are so cautious as to implement legislation against the use of CRISPR/Cas-9; many countries are apprehensive towards its use (on embryos) that they have implemented laws of prohibition. In a survey regarding policies on human germline genome editing, of the 96 countries surveyed, only 11 officially permitted such research (Baylis et al.). These countries are more technologically developed, for example the United States, China, Japan, India, and the United Kingdom. When creating laws on genetic technology, a main factor that is considered is the reproducibility of the research being conducted and how safe it is for those involved. Additionally, what is deemed as gene editing may not be consistent amongst different countries, causing confusion as to what is and is not allowed. Many countries, however, agree that genome editing should not be used for the purpose of reproduction or experimentation on embryos. In the survey with the same 96 countries, 70 of them have prohibition policies on heritable human genome editing for reproduction; no country currently permits its use. One of the first instances of embryo experimentation was carried out by the Chinese scientist, He

Jiankui. He used CRISPR to remove the gene responsible for the HIV receptors in immune cells in a set of twin girls. His actions resulted in worldwide protests and imprisonment. In order for us to be able to progress using CRISPR, we must continue performing experiments and studies, observing its effects on low stake scales.

Currently, breast cancer is the most common cancer amongst women, not just in the United States, but worldwide. On a global scale, it is one of the leading cancers, responsible for high mortality rates. Statistically speaking, one in four women are to be diagnosed with breast cancer (BCRF). To treat breast cancer, the main methods include chemotherapy, surgery, hormone, biological, and radiation therapy. Despite having all these options for patients, the journey to recovery is never an easy one. In the past years, scientists have recorded difficulties that prove to limit the effectiveness of treatments. These difficulties include identification of cancer stem cells, drug resistance, and restrictions in diagnosis (Chakraborty and Rahman). Drug resistance poses a large issue to chemotherapy. Researchers have conducted studies on cancer patients and held experiments using CRISPR on animals, as models for human disease, to see whether various genes are responsible for improving survival rates, slowing cancer, or fighting off unwanted cells (Connolly et al.). Seeing improvement in the state of health in animal models for cancer, provides hope that one day, we may be able to apply such technology to benefit humans. CRISPR/Cas-9 is proving itself to have the potential to be a future treatment option for breast cancer.

This paper explores the potential applications of CRISPR/Cas-9 as a treatment for breast cancer, while addressing the ethical constraints associated with its implementation. Topics of financial, ethical, legal, emotional, and physical responsibility will be covered, including other ethical concerns regarding the technology and the nuance that could come with its application into society.

Research approaches to the treatment of breast cancer using CRISPR

Currently, researchers are conducting experiments utilizing CRISPR, to better understand how it can be applied to the treatment of triple negative breast cancer (TNBC). They have done so by using CRISPR to induce mutations in a variety of models, ranging from animals to human organoids, which are not to be confused with real organs. Organoids are engineered cell-based tissue, which encapsulates the essential structure and function of its respective organ (Barbuzano). In many works, mice have been used as models to observe the result of the application of genetic mutations. They are used for a variety of studies, with one specific instance being the application of genetic technology on *in vivo* (whole living organisms) mouse models to identify tumor suppressor genes that are involved in breast cancer (Pont et al.). However, mice and other laboratory animals are not always able to replicate the attributes of a cancer model. Therefore, scientists are working on developing other models, one that's gaining attention is organoids. Scientists have used human organoids to model TNBC and its responsiveness to current treatments, namely chemotherapy and immunotherapy (Jiang et al.). These experiments allowed scientists to better understand links to breast cancer. They were able

to identify several genes associated with the progression of breast cancer tumors. The identified genes can be used as biomarkers for future diagnosis and therapy methods. As CRISPR is still in its early stages, researchers have to be innovative with their experimenting to extract the information they need, while not directly testing on humans.

This genetic technology has seen fast development and progression. Even so, it is still in its infancy and there are many uncertainties pertaining to its use as a treatment for breast cancer. The chances of off-target effects, lack of delivery systems, and nonspecific cleavage all pose as limitations to using CRISPR on humans. These factors are interconnected: if the Cas protein fails to cleave the target region, it can result in the off-target effects. These effects have the potential to cause genotoxicity which is associated with the progression of cancer, meaning that CRISPR currently comes with the risk of worsening cancer rather than treating it (Tiwari et al.). Although there are technologies being created to prevent some of these risks, studies have reported the immunological dangers that would come with using genetic editing on humans, and the responses already observed in human cells (Tiwari et al.). From this, conclusions can be made that safety is a large concern when looking at CRISPR as a treatment for breast cancer.

It is difficult to say how the future of CRISPR/Cas-9 will look in breast cancer. Glancing back on the progress and discoveries that it has made so far, there is an optimistic future for CRISPR as a therapy or treatment for breast cancer. To make this true, scientists will have to further advance the precision and quality of sgRNAs and have a stronger grasp on the potential risks of the procedure. sgRNAs, single guide RNAs, are the component of the CRISPR system which guides and directs proteins to the targeted region. The performance of sgRNAs can be optimized by properly cutting ends off, to make them grasp on to the target region more efficiently. However, if done improperly, it can cause increased risk of off-target side effects (Feng et al.). With how many researchers rely on models as the source for testing the effects of CRISPR, they may face the challenge of regulations being implemented. In protection of animal safety, the legislature has indicated the approach towards policies that will restrict the use of CRISPR on such subjects. This can lead to a stop to the use of animals as models for cancer in research, holding back the development of the technology (Pont et al.). While CRISPR/Cas-9 has the potential for treating breast cancer, its application remains in early stages due to concerns like off-target effects and immunological risks.

Financial and legal concerns of CRISPR-Cas9 for the treatment of breast cancer

Focusing solely on the cost of utilizing this tool, it is not one that can be afforded by anyone. Even for non-CRISPR gene therapies, pricing can range from $400,000 to $2 million for a single treatment (Subica). For the aforementioned CRISPR treatment to sickle cell disease, the cost is approximately $2.2 million per treatment. Looking at the cost rates for CRISPR within research purposes, basic components each cost between $1,000-5,000. For guaranteed rates of main services, prices can vary from $11,000-20,000, with basic components included. While the technology for CRISPR may appear to be highly expensive, in comparison to other gene editing tools, it is considered cost-efficient. It only requires the programming of two primary molecules,

which can easily be adjusted, whereas other options need more time to be executed because they use protein engineering (Thomas).

Simply looking at the costs of current breast cancer treatments, expenses can range from around $48,000 to $182,000, for stage 0 to stage IV breast cancer, respectively (WebMD Editorial Contributors). These expenses are not one-time payments. There are often several rounds of treatments and patients will have to pay higher costs as the cancer worsens. For a large portion of people, these fees may be covered by their health insurance, however that is not the case for everyone. Paying medical fees without insurance can cause detrimental financial burdens. This prevents people from receiving the necessary help for their bodies. Moreover, treatments that are not necessary for one's health or are too costly are often not entirely covered by health insurance. This would likely happen with CRISPR as a treatment, as there are existing treatments to breast cancer which are much more affordable for insurance companies to subsidize.

With each treatment costing millions of dollars, it is certain that not everyone will be able to afford the treatment, even with health insurance. The cost is simply too expensive for the vast majority to be able to benefit from. Only those of the highest socioeconomic status will have the privilege to reap the benefits of the treatment. This will consequently result in the deepening of existing inequalities in medicine. Beyond taking advantage of CRISPR as a solution for breast cancer, people may attempt to use CRISPR as a tool to enhance selected traits (e.g. height, hair color, etc.). This is where legislation plays a role. How far can this technology go? At what point is it deemed "too far"? What is being done to regulate it? Policymakers draw the lines answering many of these questions, but there are still constantly changing factors and considerations.

In the United States, there are no explicit laws against the use of CRISPR. There is legislation regarding gene therapy, enforced by the FDA, which CRISPR technology adheres to (FDA). Gene therapy products and research are regulated by the FDA. As to protect the safety of participants in any human studies or clinical trials, the FDA evaluates the safety, efficacy, and ethics before approving them. As clinical trials progress through the phases, the studies reach larger groups of people. Drugs/procedures can only be offered to the public after approval is given by the FDA in the final phase. Academic and medical institutions, and biotechnology companies tend to be stronger supporters of experimenting with the technology as it works to advance their studies and scientific innovation. These groups play their role in working with legislation to determine what should be regulated, what is safe, and any reframing of the regulations already established. While doing this, they tend to sway the reasoning in their favor, as to allow them to continue and expand their scientific work. Aside from these organizations, there are also groups that promote access to innovative therapies while ensuring patient safety, for instance CRISPR Therapeutics. They host patient organizations that collaborate with the community to educate patients and advocate for research, funding, and treatments. They work with a multitude of organizations, supporting different diseases, namely oncology with the American Cancer Society. Safety and efficacy are what policymakers and researchers hold at the forefront of decision-making when it comes to the application and experimentation of CRISPR.

Moral concerns of CRISPR-Cas9 for the treatment of breast cancer

While the physical uncertainties are a large concern that surround CRISPR as a potential treatment of breast cancer, another factor is the individualistic perspective. Some people greatly value their own free rights and individualism; CRISPR can pose a threat or question to these values, as genetic therapy can potentially be interpreted as genetic alteration and a shift from natural to artificial variation. Spiritual and personal reasons play a large role in the willingness to engage in this type of treatment, along with the type of culture an individual belongs to (National Academies).

For those that follow the individualistic culture in health care, their choices mean a lot to them; they view medical treatment as a personal freedom and right, and not a forced matter (Sabin) Those who are part of an individualistic culture are more geared towards their personal values and goals and are not afraid to stick to them, if it means not following current health trends (Nickerson). Within healthcare, individualism can be observed in the way patients choose to listen to medical advice (Okely et al.). Often, they perceive it as a suggestion and advice rather than a rule to follow, doing what they think is best for their bodies. For example, when physicians tell their patients to take a vaccine, personal values may outweigh the advice of their physician and result in staying unvaccinated. With technology, like CRISPR, there is even less knowledge and understanding of what its long-term impacts could be, providing more reason for individualists to be on edge about treatment. In contrast to the individualistic culture, there are collectivistic cultures. Collectivist cultures value social trust and reciprocity; this has been recorded to have a correlation with positive health outcomes. (Kawabata) Collectivists will work collaboratively to emphasize healthcare within their communities. For example, communities have come together to implement public health initiatives and vaccination programs, in order to promote accessible healthcare (Okely et al.). Reacting to new options as a group, collectivists will be more willing to participate, knowing trust is upheld within their community.

In addition to being affected by surrounding culture, there is concern around how the utilization of CRISPR may affect society and the development of personality. There is the fear that CRISPR may go beyond its required use as a treatment and be used to correct genetic “flaws” as to maximize an individual's performance. To use CRISPR for any sort of mutation may instill fear in people that change to their everyday life will occur. There are two types of genetic mutations, germline and somatic. Germline mutations occur in the body’s reproductive cells and are passed down from one generation to the next. Somatic mutations affect the cells outside the reproductive system and therefore do not have effect on future generations. Therefore, the use of CRISPR as a treatment for breast cancer would be categorized as a somatic mutation. Individuals are concerned about the unprecedented effects that may result from such new technology. Even though future generations may not be altered, what about themselves? Are they willing to see the risks in their own bodies? CRISPR's potential treatment for breast cancer raises concerns about physical uncertainties and challenges individualistic perspectives, where autonomy is highly valued, potentially seeing genetic therapy as altering natural variation.

Cultural and personal beliefs heavily influence willingness to engage in such treatment, with individualistic cultures emphasizing personal choice and collectivist cultures relying on social trust. There's also hesitation about CRISPR's societal impact, with fears it may not only treat but also alter personalities, undermining the value of natural genetic diversity.

Conclusions & Future Directions

Breast cancer, one of the most strenuous health conditions faced by women, has been presented with the potential to utilize CRISPR as a treatment option in the future. The developing technology has shown its capability to help address and treat diseases within humans. Despite the wide variety of breast cancer treatments available to patients, they don't always work for everyone. CRISPR as a potential treatment for breast cancer could be the cure to treating patients who have experienced resistance to other existing methods. However, with such hope comes doubt. Concerns have surfaced regarding taking the step forward to using CRISPR for this purpose. The technology's current uses in agricultural and health sectors instill optimism amongst scientists that it can be further expanded to treat medical conditions, but within the public eye, there is still much hesitation.

CRISPR is a new technology that has seen rapid growth and development. So far, there have been numerous lab studies conducted showing the extent to which CRISPR can be used for genetic discovery and modification (Connolly et al.), including sickle cell disease. CRISPR has led to breakthroughs in various fields, including agriculture, medicine, and biotechnology, by facilitating advancements like gene therapy, disease resistance in crops, and the study of genetic diseases. Despite its progression, the technology still faces many limitations and is not yet ready for the treatment of breast cancer due to limited development and insufficient human experimentation. This is because there is still uncertainty pertaining to the effects of CRISPR, so researchers often work with animal and organoid models to protect the safety of humans (Connolly et al.). In addition to the restricted expanse of research, the projected socioeconomic disparities are another concern. Not being able to afford the treatment, when it may be the last option, poses a large inequality to those who are not financially stable. But the inequality does not only stem on a financial level, but geographical. The technology is not available on a global scale; developing countries may not have the luxury of providing their citizens with this form of medical care. These, along with several other factors, are strongly considered in the process of introducing the use of CRISPR as a treatment to breast cancer.

CRISPR has a strong and promising future in helping to diagnose and treat breast cancer, as studies have been able to utilize the tool to identify impacted genes and related effects. As research develops, it's likely that there will be new ethical concerns that society will have to overcome. The implementation of CRISPR as a treatment for breast cancer will require the joint effort and input of many. For instance, scientists, researchers, policymakers, and the public will need to agree upon the ethics, benefits, and equity of releasing the potential treatment. These decisions will need to be made with the knowledge of the various physical and societal risks at stake. In the same way hesitation rose regarding the COVID-19 vaccine, whether it was because

of personal values, political standpoints, or other reasons, CRISPR is facing similar feelings (Pourrazavi et al.). As it is new and unfamiliar with the public, skepticism and doubt are factors which play into the opposition towards the use of CRISPR as a treatment. In the past four years, we've seen what a difference one vaccine can make. While CRISPR has only shown a glimpse of its potential, we must pursue its development to see its possible success in treating breast cancer and not let concerns from some determine the future of health for others. Despite its promise, CRISPR faces significant ethical limitations that must be addressed, including concerns over genetic privacy, equity, and long-term effects. Public interaction and continued research are crucial to harnessing CRISPR's potential to revolutionize breast cancer treatment. However, reconciling these ethical challenges is essential for its responsible and equitable application in the future of healthcare.

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Sleep Effects on Adolescent Memory and Cognitive Ability by Diya Kondur

Abstract

Sleep deprivation is currently one of the most prevalent problems in adolescents. High schoolers with 5-6 hours of sleep is almost normalized in high schools. Other than educating students about getting sleep, school systems have not done much to address the issue. Sleep deprivation has many drawbacks such as lower attention spans and focus levels, short-term cognitive impairment like slower daytime processing, and sometimes even long-term cognitive decline like Alzheimer's, higher risks of depression and anxiety, and weaker memory power. Delaying start times is an applicable solution and has the capacity, depending on the delay time of increasing high schoolers' sleep by an hour or more, positively affecting their memory capacity, concentration time, and overall performance. Nap times can also help adolescents manage sleep durations and improve cognitive abilities as well. Sleep duration, however, changes depending on different individual factors. Women are more susceptible to sleep deprivation-caused problems than men, African Americans are more susceptible than European Americans, and children and the elderly are more susceptible than adults. By understanding these differences and impacts, drawbacks of sleep deprivation can be combated by more practical solutions.

Introduction

Sleep plays a fundamental role in cognitive performance for individuals of all ages. A sufficient amount of sleep is required for people to be able to perform their daily activities without difficulty. The exact amount of sleep that would be considered as sufficient, though, varies from across the lifespan. For adults, this amount would be about seven hours of sleep a night. However, for teenagers, this amount is greater, with a recommendation of eight hours of sleep a night. Despite this increased sleep demand, teenagers are naturally less tired in the evening, specifically because sleep pressure accumulates slower compared to adults and children. Due to their late sleep timings clashing with early school start times, teenagers are often unable to get a sufficient amount of sleep in preparation for the following school day. As a result, teenagers tend to oversleep on weekends to compensate for their sleep loss. In consequence, they are not able to reach their minimum weekly sleep duration for optimal cognitive and physical health. For example, in elementary and middle school students, sleep deprivation has been shown to cause a decrease in academic functioning as well as mental health. Moreover, sleep deprivation has been reported to also have noticeable effects on the elderly. As this population is naturally more vulnerable because of their age, sleep deprivation causes a significantly higher risk of nocturnal sleep disorders and lowers their attention and concentration levels compared to healthy adults. Although these age groups are vastly different, they are all negatively affected by sleep deprivation.

Sleep is not only important for many age groups, but is also important in many aspects of health, including mental health, physical well-being, and cognitive functioning. Because sleep is

so crucial for learning and memory, students' unhealthy and unbalanced sleep schedules lead to worse academic performance in school and result in long-term impacts on overall health. This can be an increased risk for diseases, worsened mood and emotional well-being, and increased alcohol consumption and smoking. Students grow more vulnerable to depression and anxiety, and they show increased tardiness and behavioral issues in school in relation to insufficient sleep. By understanding exactly what effects sleep deprivation has on a teenager's academic performance and overall health and the benefits of sufficient sleep, we can develop better solutions to this societal problem. For example, pushing back school timings to later times has proved to positively affect high schoolers' sleep schedules and overall performance in many different studies.

Finally, although sleep deprivation can have a negative effect on people, with permanent impact found in high school students' populations, the benefits of sufficient sleep can be rewarding as well. With ample amounts of sleep, students show healthier behavioral patterns and demonstrate fewer disciplinary problems. Importantly, students do better in school in terms of academic performance as well. Additionally, sufficient sleep leads to an overall healthier lifestyle with less risk for diseases. In the end, it is important to study the disadvantages of sleep deprivation and its relationship within-school cognitive performance, as well as the overall benefits of sufficient sleep during the teenage years. This review article will provide an overview of these three topics and interconnect multiple studies to emphasize the relationship between sleep and the cognitive function of a high-school student.

Effects of Sleep Deprivation on Education Performance

Looking to address what components out of three basic cognitive processes, attention, working memory, and executive functions, are most likely to be harmed by a 24 hour sleep deprivation period, an experiment was conducted in which 23 undergraduates were split into two groups to test the effects of sleep deprivation(García et al., 2021). The groups had different tasks to do, assessing their cognitive abilities. The control group was able to perform these tasks three days in a row at noon with the ability to sleep freely, while the experimental group had to do the same tasks with one day of sleeping freely, 24 hours of no sleep, and one night of recovery. According to the result of this study, the 24 hour sleep deprivation period reduces tonic alertness, selective and sustained attention, components of attention, and component of executive function. Further, a group of adolescents who did not have a habit of sleeping less was put in two separate groups(Lo et al., 2016). The sleep-restricted group was allowed to sleep 9 hours for 3 nights, 5 hours (sleep deprivation) for 7 nights, and then three more nights of 9 hours recovery sleep. The sleep-restricted group showed a decrease in sustained attention, working memory, positive mood, and executive function, along with an increase in subjective sleepiness, and they were not able to recover in the recovery time given to them. Another study attempted to identify the relationship between the duration and quality of sleep and children's performance in important developmental domains, including cognitive functioning, academic performance, and mental health(El-Sheikh et al., 2019). Two-hundred and eighty two children participated in this experiment. Their sleep for

seven consecutive nights, actigraphy-based sleep duration, and self-reported sleep quality were collected. The children, their mothers, and their teachers also reported the childrens' mental health, and they were given cognitive performance tests. Finally, teachers reported academic functioning and schools provided academic achievement data. The results of this experiment showed that the relationship between sleep and childrens' cognitive functioning, academic achievement, and mental health are nonlinear, and the relationship between externalizing behaviors and sleep duration and quality is nonlinear negative, meaning that children have less behavioral problems with more sleep time and better sleep quality.

Sleep Deprivation Effects Across Demographics

Sleep deprivation involves the condition of physical and psychological distress resulting from a lack of sleep. This lack of sleep leads to different effects for a variety of different demographics, such as gender, age, and health conditions. For example, infants need 12-16 hours of sleep a day, while 1-2 year olds need 11-14 hours, 3-5 year olds need 10-13 hours, 6-12 year olds need 9-12 hours, 13-18 need 8-10 hours, and adults need 7 or more hours a night. Even within the age group of adults, older adults may need more sleep time, because they tend to fall asleep slower and sleep lighter than younger adults. Also, women tend to have more sleep-related complaints than men because of natural gender differences. Further, factors such as disease states, sleep quality, previous sleep deprivations, and pregnancy also affect these basic sleep requirements. Thus, the effects from sleep deprivation are tailored to the individual. As such, the requirements for daily sleep also vary in a similar manner.

Over the period of 12 months, the sleep times and depression levels of a group of 3,071 adolescents (aged 13-18 years) were measured through biannual online surveys from October 2009 to December 2012(Conklin et al., 2018). Because of developmental changes in this stage along with various environmental factors, it was noted that there were significant differences in measured CESD scores between genders. It was reported that there was no specific pattern in men, but in women, sleep deprivation increased the risk of depression significantly. Although this study was subject to bias because of its self-reported sleep times, its results still stand true because they adjusted for multiple confounders in their overall estimates. Sleep duration and quality is also affected by race(El-Sheikh et al., 2019). African Americans, for example, have poorer sleep quality and shorter sleep durations than Europeans Americans due to a variety of factors such as discrimination and prejudice that contribute to their poorer sleep qualities. Another study looked at the relationship between cognitive and emotional function, sleep time, and sleep quality in the elderly(Liao et al., 2022). 150 elderly patients over 65 years old were divided into a normal cognitive function group and a cognitive impairment group. In the results, the total score of PSQI, sleep quality, falling asleep time, sleep time, and sleep efficiency of patients with cognitive impairment were higher than those of patients with normal cognitive function.

Descriptive characteristics of young people in the BASUS cohort across levels of cumulative sleep deprivation

	History of Sleep Deprivation		
	None (n=2141)	Occasional (n=533)	Chronic (n=397)
Baseline (Wave 4* or 5)			
Female	51%	54%	61%
Age (years), mean (SD)	14.8 (0.7)	14.8 (0.7)	14.8 (0.7)
White ethnicity	54%	47%	38%
Post-pubertal stage	9%	7%	12%
High family income	44%	39%	37%
Highest maternal education	41%	37%	37%
Excellent/Good health	62%	52%	51%
BMI (kg/m^2), mean (SD)	21.0 (4.0)	20.9 (3.9)	20.8 (3.8)
Sleep duration (hr), mean (SD)	9.0 (0.8)	8.2 (0.9)	7.3 (0.8)
CESD score, mean (SD)	15.2 (10.5)	17.6 (11.0)	18.4 (11.3)
Mid-point (Wave 6)			
Sleep duration (hr), mean (SD)	8.9 (0.8)	7.9 (0.9)	7.0 (0.7)
Follow-up (Wave 7)			
Sleep duration (hr), mean (SD)	8.9 (0.8)	7.7 (0.9)	7.1 (0.7)
CESD score, mean (SD)	15.0 (10.4)	18.2 (11.0)	19.0 (11.9)
Depressed, (CESD $\geq$ 24)	20%	28%	32%

Fig 1: Data on imputed sample (n=3071). *Data on BMI from Wave 4 only. BMI, body mass index (kg/m^2); high family income was perceived as far above average/quite a bit above average

relative to peers; CESD, Centre for Epidemiologic Studies Depression Scale score; Depressed (CESD≥24)

This table was recreated from Conklin et al., BMC Public Health. 2018.

Biological Processes Disrupted by Sleep Deprivation

Sleep deprivation hinders immune response(Garbarino et al., 2021). Sleep deprivation leads to an increased risk for infectious/ inflammatory pathologies including cardiometabolic, neoplastic, autoimmune and neurodegenerative diseases. As sleep normally promotes defense against infections and diseases, the lack of it has detrimental effects on health as it makes people more prone to these diseases.Furthermore, periods of sleep deprivation negatively impact dendrites and their structure(Havekes et al., 2016). A minimal amount like five hours of sleep deprivation can decrease dendritic spine numbers in selective areas of the brain. This has been proven to lead to a weaker memory as well.

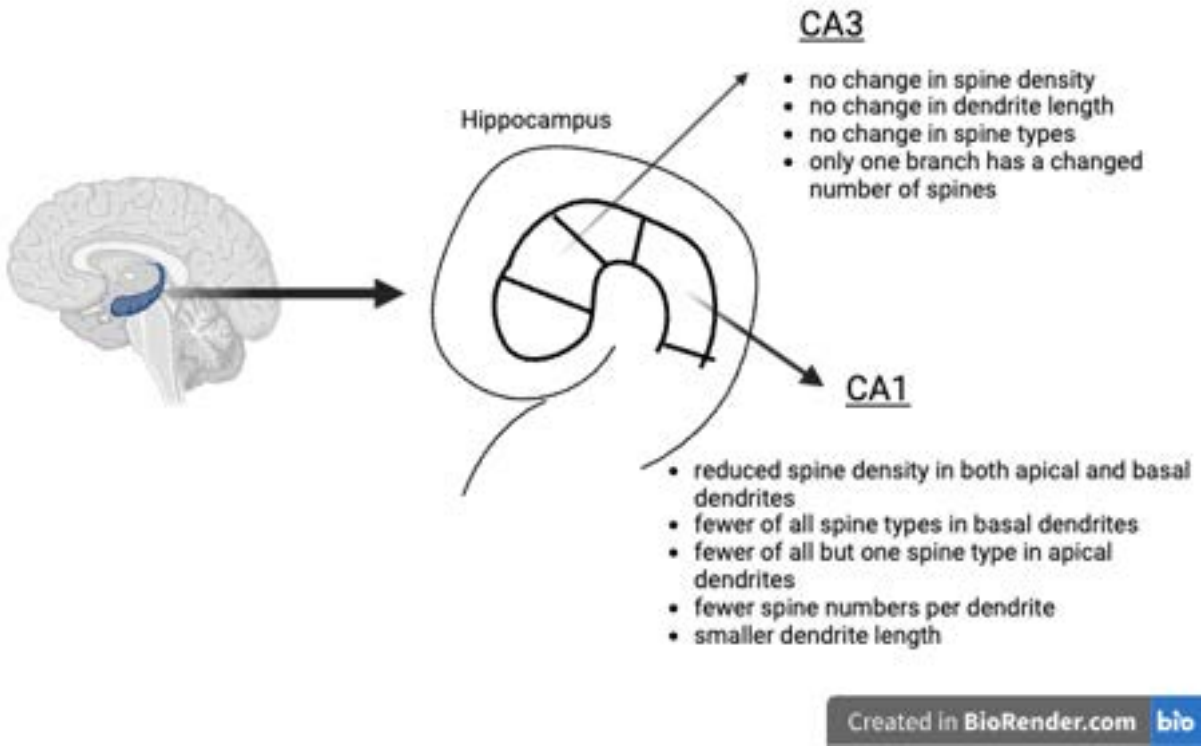

Figure 2 represents the effects of sleep deprivation on hippocampal sub-structures, CA1 and CA3. This figure was created on BioRender.

Delaying School Start Times

When students (grades 10-12) were given a choice to start school at 8:00 or 8:50, they only chose the later start minimally(Biller et al., 2022). However, when chosen, students were able to gain an hour of sleep and they showed better sleep quality leading to improved motivation, concentration, and study quality. Specifically, 45-59% of students, each time, had achieved 8 hours of sleep when picking the later start compared to 3-15% with normal school times.

When elementary students' start times were delayed by 1 hour, they showed earlier weekday bedtimes and wake times with an 11 minute sleep decrease(Meltzer et al., 2021). With different start times, elementary students' sufficient sleep duration, poor sleep quality, or daytime sleepiness did not change. Middle and high school students showed a noticeable increase in sleep duration and a decrease in daytime sleepiness. Another study, with a total of 455 students, measured the sleep duration with later school timings (Widome et al., 2020). Students got about 43 minutes more sleeping time and slept a lot less on the weekends. They also had similar bedtimes 2 years after the start time delay. Finally, a study further measured the impact a 45-minute school start time delay affected sleep, health, mood, behavior, and academics (Thacher & Onyper, 2016). This study, unlike the others, students delayed their sleep time but did not get more sleep. Regardless, they showed less tardiness and decreased disciplinary incidents.

Introducing Nap Times Into Sleep Schedules

When 53 adolescents were given either an 8 hour Nap schedule (6.5 hour nocturnal sleep with a 90-minute daytime nap) or an 8 hour No-Nap, nocturnal-only sleep schedule, the regular nap opportunities benefited building of robust and flexible schemas, facilitating recall of the subsequently rearranged and expanded structured knowledge (Aghayan Golkashani et al., 2022). When looking at how effective short daytime naps can be to help with sleep deprivation, nineteen adults were restricted to 7 nights of 5 hours of sleep(Saletin et al., 2017). Ten of those adults were unable to take naps and the other 9 were allowed a daily 45 minute nap. Their sleepiness was measured using the multiple sleep latency test and a visual analogue scale at 2-hour intervals. The results showed that the short daytime nap did decrease sleepiness, but only for a limited period of time. Thus, naps may help with sleep deprivation, but they are not a long-term solution.

Conclusion

Overall, sleep time and quality significantly affect the cognitive function of people of all ages, especially high school students. Without enough sleep, people cannot perform their daily activities to the best of their ability. Society does not emphasize the importance of sleep quite enough, as despite the prominent effect of sleep deprivation on students' lives, due to factors like school start times and workloads, students are still forced to sacrifice their sleep.

Throughout the multiple studies mentioned, results were collected in many different methods including self-reported questionnaires. These approaches included controlling sleep while monitoring cognitive effects when comparing control groups with experimental groups, and monitoring types of different sleep habits. Because of this variety, the studies chosen can be considered generalizable to the overall beneficial effects of sleep. A variety of additional data was collected that aimed to assay factors such as academic achievement data, multiple sleep latency tests, mock assignment results, PSQI (Pittsburgh Sleep Quality Index), in-school behavior, daytime sleepiness, executive function, working memory, disease risks, depression, and attention. With all of these different types of data measurements, this review connected concepts and unanswered questions across studies to understand a greater perspective on the relationship of sleep time and sleep quality specifically in a young population. Furthermore, the studies outlined in this review explored the effects of certain variables like gender, age, different start/end times, different sleep times, and different sleep schedules, which are all factors to consider when attempting to draw general conclusions to populations at large. By piecing together a variety of different study methods and experiments, this literature review uncovered certain limitations of existing primary research, however, our findings nonetheless support the existing hypothesis that sleep is crucial to the proper cognitive functioning of human beings during development.

In considering major weaknesses in existing literature covering this topic, however, we found that a major limitation to the experiments mentioned in this review primarily focus on low sample sizes. This is a considerable issue to those that want to use these findings to support systemic change in the way in which schooling is structured as it relates to students' sleep schedules. For instance, because the entire population can vary significantly compared to chosen subjects, the data may fall short of accounting for variability in lifestyles across the world and thus cannot be completely accurate. Also, while an attempt was made in these studies to account for regional variability, all of these studies did not account for variability as it relates to minority groups, including racial, ethnic, and gender minorities. Despite these limitations, however, these studies presented findings that are in the cutting edge of understanding the relationship between sleep and memory from as close to a biological perspective as currently possible. For instance, one study detailed that in healthy adults the stages of REM and slow wave sleep play major roles in memory consolidation.

In conclusion, the research detailed in this review presents data that could provide possible solutions to how sleep deprivation is present in a student population. For example, a source of chance can be to alter school hours which definitely affect the amount of sleep a student receives. However, this is not a fool-proof solution to students' sleep deprivation, as it is a more systemic approach that does not get at individual variability in student sleep schedules. These data also point to potential additional causes of sleep deprivation in youthful populations, such as addiction to social media or screen usage in the late hours. Future work should approach sleep deprivation from an angle of how internet usage or addiction to social media may be a cause for sleep pattern disturbance in high school aged students. Potential limits on the use of

these types of technologies during sleep hours may standardize sleep schedules and may thus contribute to an improvement in sleep time and quality. There are many more possible solutions that can help with sufficient sleep, and as a result of the implementation of such solutions students will exhibit better overall grades, longer attention spans, more concentration, better behavior, less risks of depression, anxiety and other health problems as well as an overall stronger memory. While the biological root of sleep disturbances in high school age students is still not completely known, we now have plenty of evidence that can drive systemic change in how students manage their sleep schedule.

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Efficient Wind Power by Alexander Cheng

Abstract

Effective harnessing of wind power is one of the sustainable solutions to our modern energy crisis and mitigating global warming. Even though the physical principle behind it is well understood, converting kinetic wind energy to electricity is an extremely complex engineering process. The entire design of the wind turbine electro-mechanical system is ultimately a multivariable optimization problem to solve. In this research project, we aim to design homemade wind turbines to understand the underlying physics principles and optimization nature. The project has two parts: (1) How to harness wind power in the most efficient way; (2) How to generate electrical power from the wind turbine's kinetic energy. The inquiry aims to connect theoretical principles to real-life engineering experience and immerse us in the scientific research methodology and engineering design process. With limited time and resources, we initially focus on the first part, i.e., the turbine design.

For a homemade wind turbine, common contributing factors include wind source, blade shape/size, and blade arrangement (installation orientation, count of blades). We hypothesize that of the three chosen independent variables, i.e., blade shape/size, installation angle, and count of blades, there is an optimal value for each to achieve the maximum output voltage under the same wind source, and there are no linear relationships.

To carry out experiments to verify the hypothesis, after some failures of initial ideas, we settled on an improved idea: designing and building blades from painted popsicle sticks, designing and 3D printing the hub for a light-load toy motor and assembling the testing structure on a bench with a leaf blower as the wind source.

Three experiments were designed and conducted to find out the different relationships of the output voltage between (1) blade shapes (Shapes A~F); (2) blade installation angles (30°~60°); (3) counts of blades (Count 3~12). We took 20 measurements per level for each of the chosen independent variables (Shape - 6 levels, Installation angle - 7 levels, Count - 8 levels). For Experiment 1 (Shape), we designed 6 different blade shapes for testing and obtained 120 data points. For Experiment 2 (Installation Angle), we used 3D printers to print out different hubs with installation angles of 30°, 35°, 45°, 50°, 55°, 60°, and 57.5°, respectively, and obtained 140 data points. For Experiment 3 (Count of Blades), we kept the installation angle at 45° and used C-Type blades but changed the blade counts between 3, 4, 6, 8, 9, 10, 11, and 12, obtaining 160 data points.

The collected raw data were entered into Excel and analyzed. Three t-tests indicated that there is clear significance between the optimal parameter and the next best one in the same experiment. Variation analyses clearly showed that the three sets of data all have very good consistency. The data analysis showed that (1) the C-Type shape produces the highest voltage among all, and the E-Type shape comes next. (2) the 55°-degree blade produced the highest voltage among all, and the 57.5°-degree one produced the second-highest voltage. (3) the

six-blade design produced the highest voltage, and the 3-blade design produced the second-highest voltage.

Altogether, there are no linear relationships, but optimal parameters exist for each contributing factor. This proves that for any wind turbine design, we will need to perform a series of real-life experiments to find the optimal parameters of the design, and this is very time-consuming but necessary. The whole design is a multivariable optimization problem for different ranges of wind speed, and the design will need some self-adjustments to achieve optimal efficiency under variable wind conditions.

Introduction

With the limited natural resources on Earth but increasingly fast consumption, we are looking for renewable energy sources like solar, hydraulic and wind, and seeking better ways to efficiently harness such energy. The mechanical energy from water or wind cannot transfer far distances, thus needs to be converted to electricity for wider usage and longer distance transfer [1,2].

Converting kinetic wind energy to electricity is an extremely complex engineering process [3,4,5,6,7], even though the physical principle behind it is well understood [8,9]. Still, we can design some simple home-made experiments to understand the underlying physics principles. This research project has two parts: (1) How to harness the wind power in the most efficient way, i.e. focusing on the wind turbine design, including the number of the turbine blades, arrangement of the blades, shape (area, geometric profile and 3D shape) of the blades etc.[5,6,7] (2) How to generate the electrical power from the wind turbine's kinetic energy, i.e. focusing on generator design, including number of wiring, schema of the wiring, material of the wiring, etc. [6,7]

This inquiry project aims to connect the theoretical principles to real-life engineering experience and immerse us in the scientific research methodology and engineering design process. With limited time and resources, we will initially focus on the first part, i.e., the turbine design.

For a home-made wind turbine, the most common contributing factors includes, but not limited to, wind speed and strength and direction, blade shape/size, arrangement of the blades (blade installation orientation, count of blades in a turbine).

Methods

Of the three chosen independent variables, i.e. (1) blade shape/size (shape A~F), (2) installation angle (0~90 degrees) and (3) count of blades (3~12, physically maximum possible number in this experiment), there is an optimal value for each to achieve the maximum output voltage under the same the wind source (speed and direction), and they are not linear relationships. For a real engineering design, it becomes a multivariable optimization problem to solve, and with self-adjustment of blade angle, based on real-time wind speed, incoming wind direction and wind turbine safety.

To carry the experiments to verify the hypothesis, we first brainstormed on ideas and chose the wind tunnel one: design and 3D print blades of different shapes and sizes (9+ iterations), construct a wind tunnel with a standing fan, and assemble the testing structure with bike dynamo and test. The testing structure did not work, and the failure was thoroughly analyzed—the wind is not strong enough to drive the turbine, and the 3D-printed blades/turbine are too small or too fragile to handle, and the bike motor is too heavy to be driven by this home-made turbine.

Then we decided on an improved idea: design and build blades from painting pop sticks, design and 3D print the hub to a light-load toy motor, and assemble the testing structure on a bench with leaf blower as the source of wind. This idea works.

Figure 1. The testing illustrations

Three experiments were designed and conducted to find out the different relationships of the output voltage between (1) blade shapes (shapes A~F); (2) blade installation angles (30~60 degrees); (3) counts of blades (count 3~12). Totally 20 measures were collected for each chosen independent variable (shape, installation angle, count).

For Experiment 1 (Shape), we designed six different blade shapes for testing. We had thought the E- Type would have the best performance, but the test result disapproved it. The blade shape/size, weight and mass distribution together determine the overall efficiency of the blade design. It turned out that the simplest design C-Type out-performed all the others.

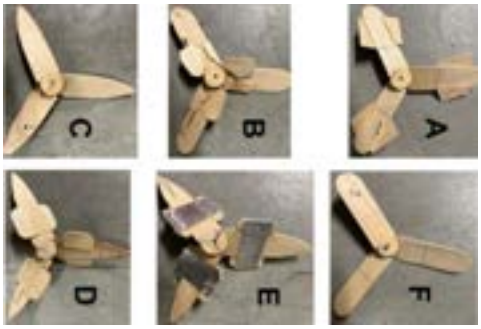

Figure 2. The six different shapes of 3-blade design (installation angle at 45°)

For Experiment 2 (Installation Angle), we used 3D printers to print out different hubs that has installation angles 30°,35°,45°,50°,55°,60° respectively. Again, the 45° designs one was not the best as expected, but the highest output came out between 50° and 60°, so we add a new blade design of 57.5° installation angle, which indeed turned out to be the optimal design.

Figure 3. The seven different 3-blade designs of different installation angles (30°, 35°, 45°, 50°, 55° , 57.5°, 60°, C-Type)

For Experiment 3 (Count of Blades), we kept the installation angle at 45° and used C-Type blades, but changed the blade counts between 3, 4, 6, 8, 9, 10, 11, and 12. The maximum count 12 was determined by the quality of the 3D printer and dimensions of the blades.

Figure 4. The eight different n-blade designs (3, 4, 6, 8, 9, 10, 11, 12 counts, installation angle at 45 degrees, C-type).

The three experiments, after multiple iterations of fine-tuning of the whole test structure, were conducted on three different days in the garage. We keep the testing environment and overall conditions the same, e.g., the leaf blower has constant power supply, the test configuration the same.

Data Analysis & Results

The collected raw data were entered into Excel and analyzed. Three t-Tests were performed to find out if there is any significancy between the optimal parameter and the next best one in the same experiment. Three variation analyses were performed to check the data consistency for each experiment.

Blade Shape				Voltage						
	1	2	3	4	5	6	7	8	9	10
A	5.07	5.16	5.21	5.16	5.14	5.174	5.14	5.14	5.15	5.10
B	5.10	5.06	4.98	5.03	5.02	5.03	5.12	5.08	5.09	5.05
C	5.72	5.73	5.73	5.70	5.71	5.75	5.71	5.71	5.78	5.72
D	4.78	4.73	4.80	4.80	4.80	4.84	4.83	4.78	4.75	4.78
E	5.19	5.15	5.17	5.19	5.16	5.17	5.19	5.17	5.19	5.18
F	4.86	4.99	5.01	4.97	4.89	4.91	4.99	4.92	4.90	5.01

Blade Shape				Voltage							
	11	12	13	14	15	16	17	18	19	20	MEAN
A	5.10	5.17	5.16	5.09	5.14	5.14	5.12	5.15	5.25	5.21	5.15
B	5.05	5.00	5.09	5.06	5.05	5.07	5.13	5.09	5.03	5.13	5.06
C	5.67	5.69	5.68	5.65	5.65	5.54	5.62	5.65	5.72	5.67	5.69
D	4.76	4.74	4.85	4.78	4.76	4.70	4.76	4.70	4.80	4.70	4.77
E	5.17	5.23	5.17	5.19	5.19	5.18	5.19	5.19	5.19	5.21	5.8
F	4.96	4.87	4.90	4.92	4.92	4.98	4.75	4.90	4.80	4.85	4.92

Table 1. Raw Data for Experiment 1 – Output Voltage vs Different Shapes of Blades

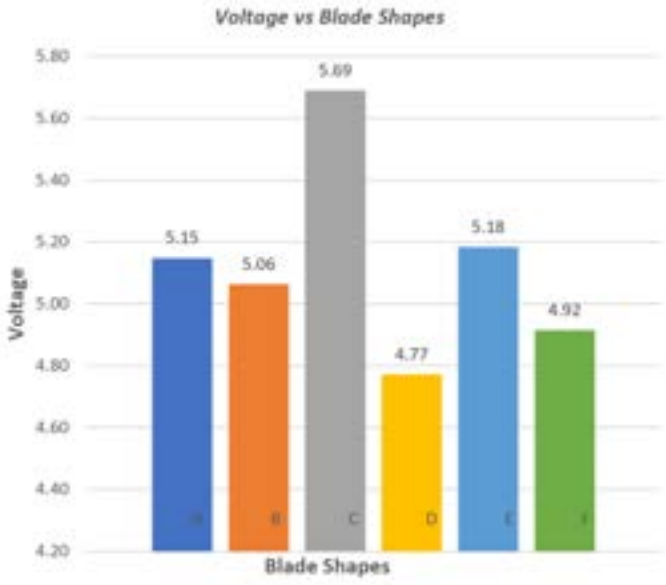

Figure 5. The average voltage produced from the different shaped blades. The C-Type shape produces the highest voltage among all, and the E-Type shape comes next.

	C-Type	E-Type
Mean	5.69	5.1835
Variance	0.002736842	0.000308158
Observations	20	20
Pooled Variance	0.0015225	
Hypothesized Mean Difference	0	
df	38	
t Stat	41.04883151	
P(T<=t) one tail	2.18372E-33	
t critical one-tail	1.68595446	
P(T<=t) two-tail	4.36743E-33	
t critical two-tail	2.024394164	

Table 2. The t-Test Summary for Experiment 1 (Shape) Note: $p<0.01$, which means that C- Type shape produces significantly higher voltages than E-Type shape blade.

Degrees				Voltage						
	1	2	3	4	5	6	7	8	9	10
30	1.63	1.63	1.63	1.66	1.63	1.70	1.71	1.65	1.65	1.68
35	1.99	1.95	1.97	1.96	1.99	1.97	1.98	1.98	1.99	1.98
45	2.80	2.85	2.85	2.85	2.84	2.85	2.83	2.84	2.85	2.85
50	3.32	3.28	3.24	3.23	3.27	3.33	3.30	3.32	3.29	3.27
55	4.78	4.73	4.80	4.80	4.80	4.84	4.83	4.78	4.75	4.78

57.5	4.26	4.25	4.25	4.25	4.23	4.24	4.24	4.24	4.25	4.28
60	3.33	3.35	3.29	3.36	3.4	3.35	3.32	3.42	3.38	3.37

Degrees				Voltage						
	11	12	13	14	15	16	17	18	19	20	MEAN
30	1.69	1.67	1.69	1.70	1.67	1.68	1.68	1.70	1.67	1.67	1.67
35	1.94	1.97	1.968	1.97	1.95	1.99	1.94	1.97	1.97	1.95	1.97
45	2.85.	1.81	2.80	2.77	2.82	2.80	2.85	2.88	2.84	2.90	2.84
50	3.32	3.34	3.25	3.21	3.32	3.28	3.29	3.28	3.28	3.29	3.29
55	4.76	4.74	4.85	4.78	4.76	4.70	4.76	4.70	4.80	4.70	4.77
57.5	4.29	4.26	4.28	4.26	4.21	4.20	4.28	4.27	4.28	4.26	4.25
60	3.35	3.37	3.31	3.28	3.28	3.27	3.30	3.30	3.26	3.38	3.33

Table 3. Raw Data for Experiment 2 – Output Voltage vs Different Installation Angles

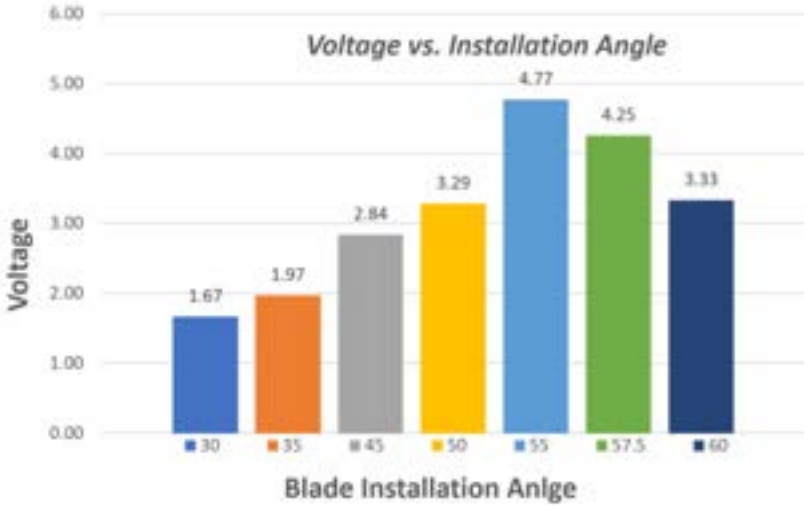

Figure 6. The 55-degree blade produced the highest voltage among all, and the 57.5-degree one produced the 2nd highest voltage.

	55 degrees	57.5 degrees
Mean	4.772	4.254
Variance	0.001932632	0.000551579
Observations	20	20
Pooled Variance	0.001242105	
Hypothesized Mean Difference	0	
df	38	
t Stat	46.47833466	
P(T<=t) one tail	2.12929E-35	
t critical one-tail	1.68595446	
P(T<=t) two-tail	4.25858E-35	
t critical two-tail	2.024394164	

Table 4. The t-Test Summary for Experiment 2 (Installation Angle) Note: $p<0.01$, which indicates the 55- degree installation blades produced significantly higher voltages than the 57.5-degree one.

# of Blades					Voltage					
	1	2	3	4	5	6	7	8	9	10
3	5.07	5.16	5.21	5.16	5.14	5.17	5.14	5.14	5.15	5.10
4	5.10	5.06	4.98	5.03	5.02	5.03	5.12	5.08	5.09	5.05
6	5.72	5.73	5.73	5.70	5.71	5.75	5.71	5.71	5.78	5.72

8	4.78	4.73	4.80	4.80	4.80	4.84	4.83	4.78	4.75	4.78
9	3.16	3.17	3.17	3.15	3.13	3.11	3.17	3.08	3.11	3.13
10	3.23	3.22	3.22	3.22	3.20	3.21	3.23	3.22	3.24	3.23
11	3.23	3.22	3.24	3.25	3.24	3.23	3.24	3.26	3.24	3.25
12	3.09	3.11	3.09	3.09	3.11	3.11	3.10	3.10	3.10	3.11

Blade Shape					Voltage						
	11	12	13	14	15	16	17	18	19	20	MEAN
3	5.10	5.17	5.16	5.09	5.14	5.14	5.12	5.15	5.25	5.21	5.15
4	5.05	5.00	5.09	5.06	5.05	5.07	5.12	5.09	5.03	5.13	5.06
6	5.67	5.69	5.68	5.65	5.65	5.54	5.62	5.65	5.72	5.67	5.69
8	4.76	4.74	4.85	4.78	4.76	4.70	4.76	4.70	4.80	4.70	4.77
9	3.14	3.18	3.13	3.15	3.14	3.16	3.17	3.18	3.17	3.18	3.15
10	3.23	3.23	3.24	3.24	3.24	3.24	3.25	3.22	3.24	3.29	3.23
11	3.25	3.24	3.24	3.26	3.25	3.25	3.25	3.25	3.25	3.25	3.24
12	3.08	3.10	3.10	3.10	3.10	3.09	3.09	3.08	3.09	3.07	3.10

Table 5. Raw Data for Experiment 3 – Output Voltage vs Different Counts of Blades

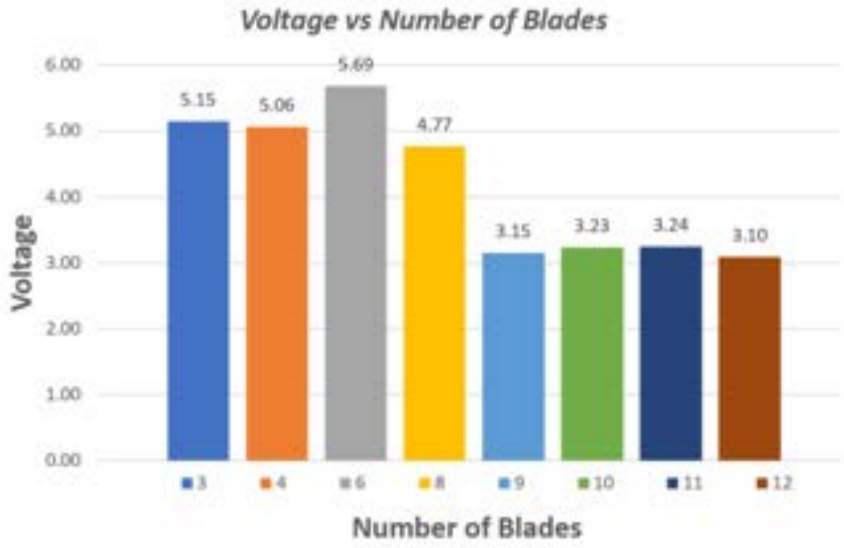

Figure 7. The average voltage produced by designs of different numbers of blades. The six-blade design produced the highest voltage and the 3-blade design produced 2nd highest voltage.

	6	3
Mean	5.69	5.1485
Variance	0.002736842	
Observations	20	20
Pooled Variance	0.002280395	
Hypothesized Mean Difference	0	
df	38	
t Stat	35.8586096	
P(T<=t) one tail	3.27476E-31	
t critical one-tail	1.68595446	
P(T<=t) two-tail	6.54953E-31	
t critical two-tail	2.024394164	

Table 6. The t-Test Summary for Experiment 3 (Count of Blades) Note: $p<0.01$, which indicates that the six-blade design produced significantly higher voltage than that of the three-blade design.

Discussion & Conclusion

Variation analyses were performed on the three data sets, and the results are listed in the tables, i.e., Table 7 ~ Table 9 below.

Blade Shape	Quartile1 Voltage	Quartile3 Voltage	Inter-quartile Range (IQR) Voltage	Lower Range Voltage	Upper Range Voltage	Outliers Voltage	Range Voltage	Mean Voltage	Standard Deviation(SD) Voltage	Coeffic-ient of Variation (CV)
A	5.14	5.17	0.03	5.10	5.22	5.07, 5.09, 5.25	0.18	5.15	0.04	0.81%
B	5.03	5.09	0.06	4.94	5.18	NO	0.15	5.06	0.04	0.80%
C	5.67	5.72	0.05	5.60	5.80	5.54	0.24	5.69	0.05	0.90%
D	4.75	4.80	0.05	4.68	4.88	NO	0.15	4.77	0.04	0.90%
E	5.17	5.19	0.02	5.17	5.22	5.23	0.08	5.18	0.02	0.33%
F	4.89	4.98	0.09	4.76	5.12	4.75	0.26	4.92	0.07	1.36%

Table 7. Variation Analysis of Raw Data for Experiment 1 (Shape) Note: There are only 6 outliers out of the 120 data points and all these outliers are close to lower or upper range limits. The data have very small SDs and CVs.

Blade Shape	Quartile1 Voltage	Quartile3 Voltage	Inter-quartile Range (IQR) Voltage	Lower Range Voltage	Upper Range Voltage	Outliers Voltage	Range Voltage	Mean Voltage	Standard Deviation(SD) Voltage	Coeffic-ient of Variation (CV)
30	1.65	1.69	0.04	1.59	1.75	NO	0.08	1.67	0.03	1.51%

Blade Shape	Quartile1 Voltage	Quartile3 Voltage	Inter-quartile Range (IQR) Voltage	Lower Range Voltage	Upper Range Voltage	Outliers Voltage	Range Voltage	Mean Voltage	Standard Deviation(SD) Voltage	Coefficient of Variation (CV)
35	1.96	1.98	0.02	1.93	2.01	NO	0.05	1.97	0.02	0.81%
45	2.82	2.85	0.03	2.78	2.90	2.77	0.13	3.29	0.03	1.03%
50	3.27	3.32	0.05	3.20	3.40	NO	0.13	3.29	0.03	1.03%
55	4.75	4.8	0.05	4.68	4.88	NO	0.15	4.77	0.04	0.90%
57.5	4.24	4.28	0.04	4.18	4.34	NO	0.09	4.25	0.02	0.54%
60	3.3	3.37	0.07	3.20	3.48	NO	0.16	3.33	0.04	1.35%

Table 8. Variation Analysis of Raw Data for Experiment 2 (Installation Angle) Note: There is only one outlier out of 140 data points and this only outlier is very close to the lower range limit. Both Standard Deviation and CV are also very small.

Blade Shape	Quartile1 Voltage	Quartile3 Voltage	Inter-quartile Range (IQR) Voltage	Lower Range Voltage	Upper Range Voltage	Outliers Voltage	Range Voltage	Mean Voltage	Standard Deviation(SD) Voltage	Coefficient of Variation (CV)
3	5.14	5.17	0.03	5.10	5.22	5.07, 5.09, 5.25	0.18	5.15	0.04	0.81%
4	5.03	5.09	0.06	4.94	5.17	NO	0.15	5.06	0.04	0.80%
6	5.67	5.72	0.05	5.60	5.80	NO	0.24	5.69	0.05	0.90%
8	4.75	4.80	0.05	4.68	4.88	NO	0.15	4.77	0.04	0.90%

Blade Shape	Quartile1 Voltage	Quartile3 Voltage	Inter-quartile Range (IQR) Voltage	Lower Range Voltage	Upper Range Voltage	Outliers Voltage	Range Voltage	Mean Voltage	Standard Devita-tion(SD) Voltage	Coeffic-ient of Varia-tion (CV)
9	3.13	3.17	0.04	3.07	3.23	NO	0.10	3.15	0.03	0.85%
10	3.22	3.14	0.02	3.19	3.27	3.29	0.09	3.23	0.02	0.55%
11	3.24	3.25	0.01	3.23	3.27	3.22	0.04	3.24	0.01	0.30%
12	3.09	3.10	0.01	3.08	3.12	3.07	0.04	3.10	0.01	0.35%

Table 9. Variation analysis of raw data for Experiment 3 (count of blades) Note: There are just 6 outliers of 240 data points and these outliers are very close to lower or upper range limits. It has very small ranges, standard deviations and CVs as well.

We can clearly see that the three sets of data all have very good consistency, i.e., few outliers, small standard deviations, and small coefficients of variations.

In Experiment 1 (Shape), for the same size, installation angle (45º) and count of blades (3), the shape C-type design obviously has the greatest efficiency and produces significantly higher output voltage than the rest of shape designs.

In Experiment 2 (Installation Angle), for the same shape (C-type) and size and count of blades (3), the design of installation angle 55º clearly produces the maximum output voltage.

In Experiment 3 (Count of Blades), for the same shape (C-type) and size and installation angle (45º), the 6-blade design clearly produces the greatest output voltage.

Altogether, there are no linear relationships, but exist optimal parameters for each contributing factor. This proved that for any wind turbine design, we will need perform a series of real-life experiments to find the optimal parameters of the design, and this is very much time-consuming but necessary. The whole design is a multivariable optimization problem for different ranges of wind speed, and the design will need some self-adjustments to achieve the optimal efficiency under variable wind conditions. Luckily, in real engineering design life cycle, tools like computational fluid dynamics (CFD) software can be used to simulate the effect of the different designs. Furthermore, engineers can employ algorithms and Machine Learning (ML) to iteratively optimize designs, seeking the most efficient and cost-effective design configurations.

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when we were about to give up when facing failures and frustrations. Without their support, we would never have gone this far in this team project work.

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Predicting Figure Skaters' Scores in Their Next Competition: A Machine Learning Approach by Jiahe Tian

Abstract

At the core of this research lies a pivotal objective: revolutionizing training methodologies and enhancing athlete performance through the creation of a robust predictive model for figure skating scores in forthcoming competitions. The study's fundamental approach involves harnessing the potential of advanced machine learning techniques in tandem with an extensive dataset comprising historical performance records.

Through the amalgamation of sophisticated techniques and a comprehensive approach to data analysis, this research aims to deliver not just a predictive model but a transformative tool for the figure skating domain.

Polynomial Degree: 1
Mean Squared Error (MSE): 2387.99
Mean Absolute Error (MAE): 37.89
R-squared (R2): 0.08
==========
Polynomial Degree: 2
Mean Squared Error (MSE): 2213.85
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Polynomial Degree: 3
Mean Squared Error (MSE): 2678.77
Mean Absolute Error (MAE): 39.90
R-squared (R2): -0.03
==========
Polynomial Degree: 4
Mean Squared Error (MSE): 2703.67
Mean Absolute Error (MAE): 40.38

R-squared (R2): -0.04 By unlocking the potential of machine learning and historical performance data, the study aspires to pave the way for more informed training strategies, enabling athletes and coaches to make data-driven decisions and achieve new levels of success in the highly competitive world of figure skating competitions.

Introduction

Context

Figure skating stands at the intersection of artistry and athleticism, where athletes' performances are intricately evaluated by a panel of judges. The significance of accurate score prediction cannot be overstated, as it has the potential to profoundly impact training strategies, enhance athlete performance, and shape competitive outcomes. Unlike team sports with objective metrics, figure skating involves subjective judgment, making score prediction a challenging but essential task. This paper intends to bridge this gap by employing machine learning methodologies to predict figure skaters' scores with precision and reliability.

By delving into this unexplored territory within figure skating, the research endeavors to bridge a substantial void in the existing literature pertaining to score prediction in this sport. The overarching inquiry driving this investigation revolves around the efficacy of machine learning models in accurately forecasting the scores of figure skaters in highly competitive settings.

The methodology employed in this study encompasses a multifaceted approach, starting with meticulous data collection and preprocessing stages. A comprehensive array of data relating to skaters' past performances, competition details, judging criteria, and panel compositions forms the bedrock of this predictive model's development. The ensuing phase involves rigorous data preprocessing, where techniques like cleaning, normalization, and feature engineering are meticulously executed to ensure the dataset's readiness for modeling. Subsequently, the model development phase entails leveraging the power of machine learning algorithms to construct a predictive framework capable of discerning and extrapolating patterns from the amassed data. The model's evaluation, validation, and interpretation stages ensure its reliability and utility in accurately predicting figure skating scores, offering a potential game-changer in athlete preparation and performance optimization strategies.

Related Work

The landscape of sports score prediction research has predominantly revolved around team-based or objectively quantifiable sports, inadvertently sidelining individual, subjective sports like figure skating. While considerable strides have been made in utilizing machine learning and statistical analysis techniques to forecast outcomes in sports such as basketball and soccer, the application of these methodologies to the realm of figure skating remains largely unexplored. Studies conducted by Smith et al. (2018) focusing on basketball score prediction and Zhang et al. (2020) delving into forecasting soccer match outcomes have notably contributed to the understanding of machine learning applications in sports prediction. These pivotal studies, while centered on different sports, serve as foundational pillars, offering valuable insights into predictive modeling, feature engineering, and evaluation metrics, thereby paving the way for adapting these techniques to the intricate domain of figure skating.

The existing body of research in sports score prediction has underscored the effectiveness of machine learning methodologies in deciphering patterns and predicting outcomes within team-based sports. Liu, Meng, et al (2018) demonstrated the efficacy of advanced machine learning algorithms in analyzing basketball game statistics and player performances to predict final scores with remarkable accuracy. Similarly, Liu, Shenglan, et al (2020) delved into the

complexities of soccer match prediction, employing sophisticated models that incorporated various match-related features to forecast game results. These studies illuminate the potential of leveraging historical data and advanced analytical techniques to discern patterns and trends, thereby enhancing predictive capabilities in sports where objective metrics heavily influence outcomes.

However, the leap from team-based sports, characterized by objective metrics, to the realm of individual, subjective sports like figure skating poses unique challenges. The studies by Smith et al. (2018) and Zhang et al. (2020) provide foundational knowledge and methodologies but fall short in addressing the subjective nuances intrinsic to figure skating scoring. Therefore, while these studies serve as a springboard, their direct applicability to figure skating remains a focal point for adaptation and refinement in this research endeavor, seeking to bridge the gap between objective and subjective sports prediction methodologies.

Outline of this paper

This research paper unfolds in a structured progression: beginning with a thorough description of the dataset, followed by the implementation of diverse prediction models, subsequent presentation of numerical results, a comprehensive discussion interpreting those outcomes, and concluding with the implications and significance drawn from the study. Starting with an exploration of the dataset, the study meticulously details the multifaceted components integral to constructing a robust predictive model for figure skating score prediction. Moving forward, it scrutinizes various models, ultimately selecting a polynomial regression model, and proceeds to showcase the numerical results derived from the model implementations. The discussion section synthesizes research findings, explores real-world applications, acknowledges limitations, and suggests future research directions, culminating in a concise yet impactful conclusion highlighting the research's pivotal contributions to revolutionizing athlete training strategies in figure skating through the developed predictive model.

Methods

Dataset

The dataset employed in this study represents a comprehensive repository that encapsulates a myriad of essential components crucial for accurate figure skating score prediction. Comprising historical performance records, competition specifics, detailed skater profiles, and the intricate compositions of judging panels, this dataset serves as the bedrock for constructing a robust predictive model. However, the subjective nature of judging in figure skating and the contextual variations inherent in different competitions pose substantial challenges that demand meticulous attention during the data preprocessing phase.

Subjective judgment, an integral aspect of figure skating competitions, introduces a layer of complexity to the dataset. Judges' evaluations, influenced by individual perspectives on artistic expression, technical proficiency, and performance presentation, contribute to the inherent subjectivity. Consequently, strategies addressing this subjectivity must be incorporated

during data preprocessing to mitigate its impact on the model's predictive accuracy. Additionally, contextual variations across diverse competitions, including differences in judging standards, venue characteristics, and competition formats, necessitate a nuanced approach. Ensuring the dataset's uniformity and relevance across varying contexts becomes imperative to develop a model capable of generalizing across different competition settings.

To address these challenges, a multifaceted approach to data preprocessing is adopted. The process begins with comprehensive data cleaning, aiming to rectify inconsistencies, handle missing values, and eliminate anomalies that could distort the predictive model's training. Subsequently, normalization techniques are employed to standardize diverse data ranges, ensuring fair treatment of variables with differing scales. Categorical variable encoding techniques are also utilized to transform qualitative data into numerical representations, enabling their incorporation into machine learning models. By meticulously executing these preprocessing techniques, the dataset's integrity is upheld, fortifying its suitability for subsequent analysis and model development, while mitigating the influence of subjective judgment and contextual variations inherent in figure skating competitions.

Feature Selection and Engineering

Skaters' scores in competitive figure skating are influenced by a myriad of factors, each playing a crucial role in determining the final outcome. Historical performance serves as a cornerstone, encapsulating a skater's past achievements, consistency, and growth. An athlete's track record, including prior competition results and trends, often provides valuable insights into their capabilities and competitive edge. Routine difficulty is another pivotal aspect impacting scores; intricate choreography, technical complexity, and the execution of jumps, spins, and footwork contribute significantly to a skater's overall performance evaluation. Judges closely scrutinize the difficulty and flawless execution of these routines, which heavily sway the final scoring.

Moreover, the subjective nature of judging in figure skating necessitates an understanding of judges' tendencies. Variations in individual preferences, biases, and scoring patterns among judges can influence how a performance is appraised. Additionally, considering injury records is imperative; past injuries and their lingering effects can impact a skater's agility, confidence, and performance quality. The location of the competition also carries weight as different venues may have varying ice conditions, climates, and altitudes that can affect a skater's performance. Furthermore, the age of the skaters is a pertinent factor as younger competitors might showcase more flexibility and energy, while experienced older skaters may demonstrate refined technique and artistry.

To effectively model and predict skaters' scores, an emphasis is placed on feature selection and employing dimensionality reduction techniques like principal component analysis (PCA). Selecting the most informative features among the multitude available ensures a more focused analysis and aids in building more accurate predictive models. PCA, a statistical method, reduces the complexity of the data by transforming it into a set of orthogonal components,

capturing the variance in the dataset while minimizing redundancy. This reduction in dimensions enhances model efficiency, enabling better understanding and prediction of the factors influencing skaters' scores, ultimately refining the evaluation process in competitive figure skating.

Model Selection and Development

The research methodology involved a rigorous evaluation of several prediction models to determine their suitability for figure skating score prediction. Linear regression, decision trees, random forests, and gradient boosting were among the models scrutinized due to their applicability in handling diverse datasets and complex relationships between input features and output scores. Each model's adaptability to the nuanced nature of figure skating performance data was thoroughly assessed. The aim was to select a model that not only demonstrated robustness in handling the intricacies of the dataset but also exhibited the potential for accurate predictions.

After extensive evaluation, the polynomial regression model emerged as the primary focus for predicting figure skating scores. The choice was substantiated through a meticulous comparison utilizing the Mean Squared Error (MSE) metric across the different models. The MSE served as a critical performance indicator, allowing a quantitative assessment of prediction accuracy. By calculating the MSE for each model, the research team aimed to identify the model that exhibited the least error, signifying its superior predictive capability.

Subsequently, the selected polynomial regression model underwent comprehensive detailing of its architecture, training process, hyperparameter tuning, and validation strategy. This intricate process aimed to ensure optimal performance and generalizability of the chosen model. Hyperparameter tuning involved systematically adjusting model parameters to maximize predictive accuracy while avoiding overfitting. Additionally, a robust validation strategy was devised to assess the model's performance on unseen data, ensuring its reliability in real-world applications. The meticulous approach in model selection and fine-tuning aimed to create a predictive framework specifically tailored for accurate figure skating score prediction.

Evaluation Metrics and Performance Assessment

Evaluation metrics serve as critical benchmarks in assessing the predictive capabilities of models developed for skaters' score prediction in figure skating. Accuracy, precision, recall, and F1-score are fundamental metrics used to gauge different aspects of model performance. Accuracy measures the proportion of correctly predicted outcomes among all predictions, providing an overall assessment of the model's correctness. Precision focuses on the ratio of correctly predicted positive observations to the total predicted positive observations, indicating the model's ability to avoid false positives. Recall, on the other hand, assesses the ratio of correctly predicted positive observations to the actual positives in the dataset, highlighting the model's capacity to identify all relevant instances. The F1-score, a harmonic mean of precision and recall, offers a balanced assessment by considering both metrics, providing a single score that balances between precision and recall.

To ensure the robustness of the model and mitigate overfitting concerns, cross-validation techniques are employed. These techniques involve partitioning the dataset into multiple subsets, using some for training and others for validation. Common methods include k-fold cross-validation, where the data is divided into k subsets, and each subset is used for validation while the remaining subsets are used for training. This process helps to validate the model's performance across different data splits and reduces the risk of the model learning specific patterns in the training data that might not generalize well to unseen data.

Furthermore, to ascertain the efficacy of the developed model, rigorous comparisons against existing prediction methods and baseline performance are conducted. By benchmarking against established methods and baselines, the model's strengths and weaknesses are identified, providing insights into its relative performance in predicting skaters' scores. This meticulous comparison aids in determining the added value or advancements brought forth by the developed predictive model in the realm of competitive figure skating evaluation.

Interpretability and Visualization

In the realm of predicting skaters' scores in figure skating, interpreting the decisions made by the model is crucial for understanding its inner workings and gaining insights into the factors influencing the predictions. Techniques such as SHAP (SHapley Additive exPlanations) values and partial dependence plots play a pivotal role in unraveling the model's decision-making process. SHAP values offer a way to explain the impact of each feature on the model's predictions by attributing a value to each feature, indicating its contribution to the prediction. These values provide a comprehensive understanding of feature importance, highlighting which features significantly influence the predicted skaters' scores.

Additionally, partial dependence plots are valuable tools for visualizing the relationship between specific features and the predicted outcome while keeping other features constant. These plots showcase how changes in a particular feature impact the model's predictions, offering insights into the direction and magnitude of its effect on skaters' scores. By examining these plots, analysts and stakeholders can better grasp how different factors, such as historical performance, routine difficulty, or competition location, affect the model's predictions.

Moreover, visual representations of predicted scores and their deviations from actual scores serve as powerful aids in understanding the model's predictive behavior. Graphical displays comparing predicted scores against actual scores enable a clear visualization of how well the model performs across different instances. Analyzing these visualizations helps identify patterns, outliers, and areas where the model might overestimate or underestimate scores. This insight is invaluable for refining the model, improving its accuracy, and gaining trust in its predictions within the context of competitive figure skating evaluation.

Results

Through meticulous data collection, preprocessing, and model development stages, the research utilizes advanced machine learning techniques to construct a predictive framework

capable of accurately forecasting figure skaters' scores. Results indicate promising accuracy of the developed model, offering potential benefits such as personalized training plans and strategic adjustments for athletes and coaches. While acknowledging limitations, including data biases and external factors, the study underscores the transformative potential of accurate score predictions in enhancing athlete preparation and performance optimization strategies in figure skating competitions.

The data will be listed here:

Polynomial Degree: 1
Mean Squared Error (MSE): 2387.99
Mean Absolute Error (MAE): 37.89
R-squared (R2): 0.08
==========
Polynomial Degree: 2
Mean Squared Error (MSE): 2213.85
Mean Absolute Error (MAE): 38.69
R-squared (R2): 0.15
==========
Polynomial Degree: 3
Mean Squared Error (MSE): 2678.77
Mean Absolute Error (MAE): 39.90
R-squared (R2): -0.03
==========
Polynomial Degree: 4
Mean Squared Error (MSE): 2703.67
Mean Absolute Error (MAE): 40.38
R-squared (R2): -0.04

Discussion and Implications

The culmination of this research effort encapsulates a synthesis of profound research findings merged with a comprehensive assessment of model performance, amplifying the critical importance of precision in predicting figure skaters' scores. Through a meticulous examination of diverse prediction models and a rigorous evaluation process, this study underscores the significance of leveraging machine learning techniques in deciphering the intricate nuances of figure skating evaluations. The paper showcases how these predictive models can serve as powerful tools, offering a pathway towards more informed and accurate score predictions. By analyzing historical performance records and competition specifics, the study not only demonstrates the efficacy of the developed model but also emphasizes the potential transformative impact it could wield in the realm of sports analytics, particularly in enhancing athlete training strategies within the competitive landscape of figure skating.

Furthermore, the research extends beyond theoretical implications, delving into the realm of practical applications. The study explores tangible real-world applications that could derive substantial benefits from accurate score predictions in figure skating. Notably, the paper illuminates how these predictions could catalyze the development of personalized training plans tailored to individual skaters' strengths and weaknesses. Additionally, it highlights how accurate predictions could facilitate strategic adjustments for coaches and athletes, enabling them to adapt their routines, techniques, or performance elements based on predictive insights. Moreover, it underscores the potential for performance enhancements, suggesting that precise score predictions might pave the way for improved training regimens, mental conditioning, and overall preparation, thereby offering a competitive edge in high-stakes figure skating competitions.

While acknowledging the significant strides made, the study remains cognizant of its limitations. It underscores the inherent biases within the data and acknowledges the influence of external factors that might have affected the predictive models' outcomes. By recognizing these limitations, the research lays bare avenues for future exploration and improvement. Addressing data biases, accounting for external factors, and further refining the predictive models represent critical pathways for future research initiatives. This acknowledgment serves as an invitation for subsequent studies to delve deeper, refine methodologies, and expand the horizons of predictive modeling in figure skating, ultimately striving for greater accuracy and reliability in score prediction methodologies.

Conclusion

This research paper presents a novel approach to revolutionize athlete training and enhance performance in figure skating competitions through the development of a predictive model for skaters' scores. By harnessing advanced machine learning techniques and utilizing a comprehensive dataset comprising historical performance records, the study aims to deliver a transformative tool for the figure skating domain. The paper begins by contextualizing the importance of accurate score prediction in figure skating, highlighting the subjective nature of judging and the need for precise predictive models. It reviews related literature in sports score prediction, emphasizing the gap in research specific to figure skating and drawing upon methodologies from studies in team-based sports prediction. The paper then outlines the methodology, detailing data preprocessing techniques, feature selection and engineering, model selection and development, and evaluation metrics and performance assessment. The selected polynomial regression model emerges as the primary focus for predicting figure skating scores, with meticulous attention given to model architecture, hyperparameter tuning, and validation strategy. The study evaluates the model's performance using various metrics and discusses interpretability and visualization techniques to understand the model's decision-making process. Results showcase the accuracy of the developed model across different datasets and hyperparameters, underscoring its potential to transform athlete training strategies in figure skating. The discussion section explores the implications of accurate score predictions, including personalized training plans, strategic adjustments, and performance enhancements.

Acknowledging limitations, the study invites future research to address biases, external factors, and refine predictive models for greater accuracy and reliability in figure skating score prediction methodologies.

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Why We Need a Shift in the Social and Medical Model of Our Approach to Autism By Mackenzie Jerrold

Abstract

Autism is a neurotype experienced by over 75 million people worldwide. The DSM-5 describes autism as a developmental disorder with social communication deficits and a tendency to participate in ritualistic behaviors. In 2013, autism was renamed to autism spectrum disorder due to the heterogeneity in causes and outward behaviors of autistic individuals. The only empirical treatment for autism at the moment is the controversial applied behavioral analysis (ABA). In society, autism is often misunderstood and mischaracterized by stereotypes. These misunderstandings can lead to individuals on the spectrum feeling excluded from common activities or at a lack of general opportunities, causing feelings of rejection and loneliness. Additionally, current diagnostic materials and information sources on the topic are using harmful language to describe the traits of autistic individuals, thus further contributing to mental health issues like anxiety and depression. ABA has been criticized as trying to make autistic people more neurotypical, as opposed to accepting them for who they are and asking them for input into their treatment. Although it is important that autistic people self-advocate for their needs, paradigm shifts such as the double empathy problem and the social model of disability could change the way that treating and understanding autistic people is approached, and perhaps remove the underlying concept of normal altogether.

Introduction

Approximately one in 36 children are diagnosed with autism in the United States, with 75 million people impacted worldwide. This equates to 1% of the world's population being affected by autism, commonly known as autism spectrum disorder (ASD) (Elias, 2022). The National Institutes of Health (NIH) defines autism as a "neurological and developmental disorder that affects how people interact with others, communicate, learn, and behave" (NIH). Common traits that exist in autistic people include difficulty maintaining eye contact, obsessive interests, and a need for sameness. These traits all exist on a spectrum, and some of these traits are not even present in certain autistic individuals. Autistic people are often significantly affected mentally and may feel excluded socially. Eighty-five percent of autistic adults are unemployed, with 70-80% of autistic people having mental health issues including anxiety and depression (BeyondAutism). More concerning, people with autistic traits are more likely to attempt suicide, (Cassidy et al, 683). These statistics indicate that this is a topic in need of addressing.

Many stereotypes exist for autistic people. In reality, autism has no unifying presentation. There is no one way that an autistic person is. Just like neurotypical people, autistic people are all different. There is a lot of heterogeneity when it comes to the ASD phenotype, as every autistic person has different outward traits and inner experiences. The autism spectrum ranges from low-support needs and the ability to function with relatively few difficulties in society to high-support needs and people who are nonverbal (Rudy). This heterogeneity is also reflected in the causes of the disorder itself and may be different for each autistic person. These differences

in experiences and the fact that ASD is measured on a spectrum makes autism very hard to diagnose and treat. Overall, the quote by Dr. Stephen Shore, PhD, an autistic professor, “If you've met one person with autism, you've met one person with autism,” holds true and suggests that it is important to address an autistic person as an individual and not impose stereotypes on them.

Almost everybody in the U.S. has met someone who is autistic. Perhaps they were unrecognizable as autistic, because autism is commonly portrayed as people like the main character in Rain Man. Rain Man is a movie that was released in 1988 about the relationship of two brothers, neurotypical Charlie and autistic Raymond (nicknamed Rain Man). Rain Man is a ‘socially awkward’ routineer who engages in repetitive behaviors. This is the image that society had of autistic individuals in the 1980s. Since the release of this movie, the medical field has made significant findings and there has been great progress in many areas of society. It would therefore be expected that the autistic community has also become better understood and accepted, with more accurate representations of autistic individuals being shared with the public. Unfortunately, this is not the case. While there have been improvements to the public view of autism, autistic people are still in need of greater support in social situations, work and school environments, and sometimes even at home. While it is important that autistic people themselves are strong advocates for their needs, society should embrace autistic people for who they are and have the ability to support them. Currently there are very limited opportunities for autistic people to participate in society and everyday activities. So for what reason does most of society still see autistic people like Rain Man? Why has the narrative for autistic people not changed, despite the immense progress society has made since the 1980s? This review paper will aim to identify holes in the current structure of the way we think about ASD and modify the definition of autism as we know it.

Standard Diagnosis and Treatments

Diagnosis

The current criteria for diagnosing ASD in the U.S. is outlined in the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) and was published by the American Psychiatric Association in 2013. The current diagnostic criteria require there to be deficits in social communication, as well as restricted and repetitive behaviors. The manual states that these traits must exist during the developmental period and need not to be associated with another intellectual disability. It is, however, important to note that ASD is often present with comorbidities, including but not limited to: epilepsy, sleep disorders, ADHD, anxiety, and depression (Bennett).

Social communication

Social communication is a key aspect in the diagnosis of ASD. The DSM-V lists some possible deficits that are often seen in autistic individuals. These include difficulty maintaining conversation, lack of understanding or use of nonverbal communication (such as gestures, eye contact or facial expressions), and struggling to develop or continue relationships.

Restricted/repetitive behaviors

Some behaviors that fall under this category include the repeating of motor movements (i.e., lining up cars/toys), difficulty with a change in normal routine/desire for sameness, special interests of a high intensity, and unique reactions to sensory input.

Severity

The severity of any of the above listed traits is also noted in the diagnostic process. The diagnostician can classify the severity of a trait on a scale from one to three. A classification of one requires the least support and three requires the most.

Early identification

ASD can be identified as early as 18 months old during developmental screenings. It is diagnosed through observation of developmental and behavioral history, which can be observed by the child's caretakers. A child's stage of development at certain ages is compared to that of typically developing children. If the child's development seems to be slower than average, an autism screening may be performed. An official diagnosis may not be given until the child is older and has had some more life experiences (CDC).

Difficulties diagnosing

The current assessment for diagnosing ASD is quite difficult, as the only way to diagnose the condition is via behavioral observations. Due to the heterogeneity and broadness of the spectrum of ASD mentioned above, many autistic people are undiagnosed as they do not fit all of the criteria, especially girls. When Hans Asperger discovered ASD in 1944, the disorder was initially only observed in boys ("The 'Extreme Male Brain': An Explanation for Autism?"). While this has changed since then, there is still a much higher diagnosis rate of autism in boys than girls. Perhaps this is because autistic girls simply have different behavioral patterns than boys. Many high functioning autistic girls have learned to make eye contact or participate in social situations. They are also better at controlling their behaviors in public, making it harder for clinicians to observe typical autistic behaviors in them (Arky). This is where a biomarker would significantly improve the diagnostic process. A biomarker is something associated with a certain condition that can be tested for using blood tests, genetic testing, brain scans, etc. (NIH). Researchers have been working for years to find a biomarker associated with ASD, but they have found that the heterogeneity of behaviors associated with ASD coincides with the heterogeneity of causes. While many genes have been identified in relation to ASD, only a small percentage of autistic people share the same genetic profiles (Al-Dewik et al. 1685). Certain differences in the structure of the brain have also been identified in autistic individuals, but brain scans alone have not been effective in diagnosing autism. This leads to a very subjective, behavior-based diagnostic process, thus creating an opportunity for missed diagnoses.

Importance of an early diagnosis

While the harm associated with a missed ASD diagnosis may not be recognizable by many, an early diagnosis is important to the development of autistic individuals. The knowledge that a child is autistic allows parents to seek support early and helps both parents and kids better understand certain behaviors. Growing up as an undiagnosed autistic child can have significant negative mental health implications due to feeling isolated and different from their peers. These effects are detrimental to the long-term health of autistic people (Mitchell et al. 10). Being aware of a diagnosis early also helps parents raise their autistic kids to communicate their needs (ie be a self advocate) - something important to the success of autistic individuals later in life. The child can also join communities with kids similar to them to combat loneliness and facilitate assistance in learning. Most importantly, an early diagnosis allows clinicians and therapists to be proactive in ensuring a successful development of communication. Given that autistic children often have speech delays as a part of overall developmental delays, a late diagnosis could mean missing the gap (before 3 years of age) during which communication can properly develop in the brain. Overall, an early diagnosis can lead to the implementation of treatments early on in a child's life. The earlier a child receives treatment, the more impactful the treatment is long term ("Early Intervention for Autism").

Treatment

Currently, treatment options for ASD are very limited. While there are multiple approaches to improve the outcomes for autistic children, there are no treatments that will get rid of ASD or even remove the majority of its traits. Because of the heterogeneity of autism and the lack of knowledge about the causes associated with ASD, there is no way to approach autism pharmacologically (CDC). While coexisting conditions such as anxiety and depression can be addressed through medicinal interventions, the characteristics of autism itself are most often approached from a behavioral and developmental standpoint.

Behavioral

The most common behavioral intervention and treatment option for ASD is applied behavioral analysis (ABA) (CDC). There are many different models of ABA which have been developed throughout the years. A few examples include the Early Start Denver Model (ESDM) and Discrete Trial Training (DTT). Both of these models follow the general principles and goals of ABA, and it is recommended to start them as soon as a child receives a diagnosis (NIH). The earlier a child enters treatment, the more plastic their brain is. This allows for a more significant and permanent change in behavior. The goal of ABA is to change certain behaviors by analyzing the possible causes and effects of the behaviors (CDC). The outcome of this analysis will determine how clinicians can encourage desired behaviors and discourage undesired behaviors. Each child engages in a highly individualized treatment plan tailored towards the needs and desired outcomes of the individual and their families. Some commonly targeted outcomes of ABA are improved eye contact, communication skills, better attention and academics, and

removal of self harm and other problematic behaviors (“Applied Behavior Analysis (ABA)”). Since this is an incredibly individualized process, ABA is most commonly practiced with an individual clinician for multiple hours a week. The amount of time spent in ABA depends on the child and the family’s comfort level. It is, however, most common for ABA to take place for somewhere between 10 to 40 hours per week for 3-5 years (“How Long Does ABA Therapy Last? ”). The setting also depends on the needs of the child and it often changes throughout a treatment plan. For some children, it is beneficial to hold sessions in a clinical setting where certain skills can be practiced repeatedly. Perhaps later in the process, they can move treatment sessions to a controlled or simulated natural environment. Simulated natural environments are often a good place for autistic children to practice their social or eye contact skills as it provides a smooth transition to applying the learned concepts to more natural environments (Bernier et al.).

Developmental

Since autism affects neurodevelopment, a lot of autistic people have difficulties with developmental skills like speech, coordination, and motor skills (National Autistic Society). For these ASD-associated difficulties, developmental interventions such as speech and occupational therapy are implemented. These kinds of therapies do not directly address autism, but they provide autistic people with the skills necessary for everyday life. The ability to communicate as humans is vital to human wellbeing, and unfortunately, the voices least heard in the autistic community are the ones who are non-communicative. If used early enough in the developmental stages, speech therapy or speech language pathologists can help those who would have otherwise been non-communicative to develop spoken language. Similarly, occupational therapy could help autistic people address any sensory issues, thus increasing their desire to participate in various activities that would be otherwise difficult for individuals with sensory difficulties (“Benefits of Occupational Therapy for Autism”).

Alternative

As with most cases of neurodivergence, there are many possible paths that are successful in accomplishing the goals of autistic individuals and their families alike. That leads to a wide variety of alternative treatments available to try and help any difficult traits associated with ASD. In fact, most families do not stick with just one treatment option. Rather, it is the combination of various treatments that ultimately lead to a positive outcome (Bernier et al.). Some people have tried herbal medicine or special diets to help foster positive behavior. The use of a therapist using cognitive behavioral therapy (CBT) is also a common addition to a treatment plan. Additionally, having other adults in the autistic child's life be part of a treatment team is very helpful (Bernier et al.).

Treatment versus accommodation

When discussing treatment options, it is important to differentiate between treatment and accommodation. Treatment involves addressing the symptoms of ASD directly, through behavioral, developmental, or alternative interventions for improving a skill (Morin). The goal of a treatment is to change something. In the case of autism, the goal is to change various behaviors and the outcome for a child.

Accommodations, involve changes in various settings to help account for the various behaviors exhibited because of ASD (Morin). The goal is not to change any aspect of the person, but to find a way for them to thrive in an environment not originally suited for their needs. Examples of places where accommodations are beneficial for autistic people include school and work settings or public environments in which autism makes it hard to function fully.

The controversy surrounding ABA

ABA, the only empirically-based treatment for autism, is an intervention strategy aimed at improving socially relevant behaviors (Hendricks et al). This intervention has recently received a lot of support and pushback from various groups involved in the autistic community. The controversy around ABA stems from its origin in the 1960s. The first version of ABA was developed by Dr. Lovaas and was titled Discrete Trial Training. The methods used to promote positive behavioral outcomes included electric shocks and punishment, and these are unacceptable and no longer used today. However, many critics of ABA point to its original purpose and techniques as a reason why this kind of behavioral intervention should not still be the primary treatment option for autistic children. Additionally, autistic self-advocate Ari Ne'eman argues that ABA is simply teaching autistic children to act in a neurotypical manner and sending the signal that the natural behaviors autistic individuals engage in are unacceptable ("The Controversy around ABA").

This feeling can be difficult for young children to understand and can lead to masking, which is the hiding of aspects of one's true self, in order to be better accepted in social environments (National Autistic Society). Ne'eman also points out that the focus on eliminating 'problematic behaviors' does not account for the emotional value of engaging in these behaviors for the child. Dr. Catherine Lord, an autism researcher, recognizes the concerns of Ne'eman, but explains that ABA is meant to help a child reach their full potential in the world, not to change their thoughts and feelings ("The Controversy around ABA"). This debate about ABA has existed for a long time, and both sides have shared their opinions. The most optimal approach continues to be debated, with people from a variety of backgrounds and expertise levels contributing to the conversation.

Change in Approach

Applied Behavioral Analysis: Helpful or Harmful?

ABA is currently the only insurance-approved treatment for ASD in the United States, making it the most accessible to families with autistic children (Zauderer). Also, as the only science-backed approach to treating autism, ABA is the most trusted route of families looking to improve the outcome for their child. While there have been some positive proven outcomes of

ABA in autistic children, some meta analyses show that the efficacy of ABA is questionable. According to one meta analysis performed by Yu and colleagues (2020), there are more aspects of ASD that ABA does not address than it does. The main positive outcome of ABA was in the realm of socialization, with improved social abilities and expressive language. However, verbal communication is not the only aspect of effective socialization, even though it is the most typical. This brings about the question of whether ABA is doing more harm than good for the majority of the autistic community.

The main skills addressed in ABA for autistic people are social abilities and repetitive behaviors. Autistic people are known to be 'socially awkward' and tend to have a hard time communicating with the neurotypical population. However, is it necessary for autistic people to learn to communicate with neurotypical people, or is it the other way around? It is not the job of autistic individuals to fit into a neurotypical society, because they are not neurotypical. The social differences of autistic people often include an inability to understand facial expressions or make eye contact (CDC). These are not traits that necessarily need 'fixing'. The only reason certain therapies such as ABA aim to 'fix' these behaviors is because the neurotypical world considers them to be a problem. Autistic people engage in some of these behaviors for a reason. For example, stimming is the repetition of various behaviors and is a way for autistic people to let out stress or other emotions; it is soothing for them to repeatedly flap their arms or participate in other repetitive motions (Kotowicz). ABA should not aim to suppress these behaviors, since they are providing comfort to the autistic individual. Another focus of ABA in autistic people is their difficulty with making eye contact. Autistic people often feel that they have to choose between making eye contact and participating actively in a conversation (Kotowicz). Making eye contact is an active task for many people with autism, and it requires energy to do so. Therefore, society needs to become more accepting of all types of people and behaviors instead of forcing societal norms on the neurodivergent community. By suppressing stimming behaviors and expecting eye contact to be made, autistic people get the message that their natural way of being is unacceptable and needs to be changed. This can lead to negative self esteem and mental health issues like anxiety and depression (Cox).

When it comes to ABA's desire to improve social abilities, there are some mixed opinions, and no one answer is right for everyone. Many autistic people are non-verbal, and ABA is proven to increase the likelihood of speech developing in non-verbal autistic children (Bernier et al.). This may make ABA appealing to families with nonverbal autistic children, but it is important to note the presence of other options. For children who appear to be non-communicative at an early age, an alternative to teaching children to speak could be introducing multimodal communication. While verbal communication is preferred by society, speaking is not the only way to communicate. Since most autistic children are not motivated by social factors from a young age, using pictures or symbols to communicate (i.e., visual communication) may be easier for them to understand (Rudy). Their ability to speak is less important than their ability to communicate, and if they miss the crucial window of communication developing in the brain, they could miss their chance at having significant

control over their lives ("Speech and Language Developmental Milestones"). For that reason, treatments like ABA should be less focused on teaching autistic children to speak, and place more emphasis on teaching communication in general, no matter whether that is verbal or visual communication.

Many autistic people argue that ABA is trying to make autistic people more neurotypical ("The Controversy around ABA"). While this is not the direct purpose of the therapy, the associated goals often translate to creating a more neurotypical person. It is reasonable to say that behaviors causing injury to oneself, such as banging one's head against a wall or hair pulling, should be addressed as quickly as possible. However, these behaviors serve a purpose to an autistic person, and cannot simply be removed. The autistic person is receiving some sort of sensory pleasure through the self-injuring activity, so it is important to first look at the sensory purpose being served by the behavior. Then, it could be helpful to see when these kinds of behaviors are occurring. Perhaps when coloring, an autistic child would take pleasure in chewing on colored paper. This obviously poses health concerns and needs to be addressed. In her podcast on sensory issues and autism, Dr. Mary Barbera recommended checking on the mineral levels of things like lead, zinc and copper in the child's blood because they are often the cause for behaviors like this. Otherwise, if a child has issues with say, wearing a jacket in the wintertime, and expresses these sensory issues through self injurious behavior, the child's parents and treatment team can try to desensitize the activity. This happens by slowly practicing certain aspects of a situation until the child becomes more comfortable with it (Barbera).

For the other behaviors addressed through ABA, the extent of the treatment should be up to the autistic person. If they truly desire to fit into a more neurotypical society, then certain social aspects can be practiced. This must be done cautiously, though, so as not to cause the autistic person to mask their true selves. Masking is often the reason that autistic people go undiagnosed, but it can cause more problems than that. When autistic people mask their true selves in order to fit in better socially, even if the masked version of them is accepted by their peers, an innate fear of rejection can arise (Mitchell et al. 10). They feel that their friends do not accept their true, authentic, autistic selves, because the autistic person has never allowed them to see that side of them. This can lead to a cycle of feeling lonely and rejected, which causes mental health difficulties (Mitchell et al. 10). Therefore, it is important to leave the majority of the things being treated up to the autistic individual, with communication and self-injurious behaviors being the only exceptions. The early introduction of multimodal communication and the replacement of self-injurious behaviors with healthy behaviors which provide the same sensory experience for the autistic person could be possible remedies to these difficulties. Overall, society needs to become more accepting of all types of people, so that autistic people do not feel the need to change themselves in order to fit in. Most importantly, society does not have the right to change autistic people and their behaviors for the benefit and comfort of others. Autistic people are humans too and they have the right to choose their own path.

The Harmful Effects of Language used in the DSM

Currently, to diagnose ASD in the United States, clinicians turn to the guidelines outlined in the DSM-V, which was published by the American Psychiatric Association in 2013. The guide explains the diagnosis: "To meet diagnostic criteria for ASD according to DSM-V, a child must have persistent deficits in each of three areas of social communication and interaction plus at least two of four types of restricted, repetitive behaviors" (American Psychiatric Association). The word "deficits" implies that something is inherently wrong with the natural state of being of an autistic person. It suggests that autistic people are faulty, and are missing factors that would make them 'normal.' This vocabulary raises questions. What defines normal? And why is a diagnostic criteria causing clinicians to make a diagnosis based on how 'normal' someone is?

Late-diagnosed autistic adult Melissa Tacia poses these questions in her podcast "Oh, That's Just My Autism" during an episode related to the DSM-V (Tacia). She emphasizes that the criteria for diagnosing ASD is too vague and points to phrases such as "interests that are abnormal in intensity or focus" as evidence (American Psychiatric Association). She believes that the criteria do not provide diagnosticians with something to compare the behavior of a possibly autistic person against. Tacia also sheds light on the fact that words such as "deficit" can negatively impact the mental health of autistic people (Dinishak), and the vagueness in criteria leads to a lot of underdiagnosing in the autistic community.

Tacia mentioned in her podcast, that a large group of the autistic community remains undiagnosed with the current DSM-V guidelines in place. She argues that based on the current diagnostic criteria, clinicians are looking only for severe manifestations of behaviors listed. Therefore, those who are engaging in similar behaviors on a less obvious level (like many autistic girls) can fly under the radar. Thus, Tacia believes that a main contributor to the underdiagnoses is the type of language used in the DSM (Tacia).

The verbiage "persistent deficits" indicates a high level of severity, and "abnormal" is very vague. Another important fault of the verbiage used in the DSM, is the use of the word "symptoms" to refer to traits often present in autistic individuals. The NIH now recommends using the words traits or characteristics, instead of symptoms when referring to ASD (NIH). As mentioned before, the DSM was last published in 2013 by the APA. Since the adoption of the fifth edition of the DSM, there have been a lot of new findings for the autistic community, and autistic advocates have spoken out about various issues related to the treatment of autistic people. For example, more information has been gathered on the prevalence of autism in girls, as female children have been historically underdiagnosed when it comes to autism ("Autism in Girls and Women"). It is therefore vital that more specific descriptions and examples of ASD's presence in all genders is provided. More and more women are finding out they are autistic as adults, and wish that they had had that knowledge as kids. In response to this childhood underdiagnosis, there needs to be more variety in the diagnostic guidelines that captures the true heterogeneity that exists in the autistic community.

In modern society, neurotypical kids are often told: "it is okay to be different, there is no normal! What does normal mean anyway? If people were not different, the world would be boring!" It is good that society is shifting away from the idea of normal and accepting lots of

different people, but that narrative shifts when we start talking about the neurodivergent community. As soon as someone is different enough to be neurodivergent, there suddenly is a normal to compare them against. For autistic people, interests are “abnormal in intensity and focus”, and differences in communicating translate to “deficits in social communication” (American Psychiatric Association). This underlying concept of normal may have primarily disappeared for the neurotypical population but is still very much existent for the neurodivergent groups. This is supported by documents like the DSM, which still uses criteria based on the ‘normalness’ of behaviors to diagnose autistic people. Using language like “deficits” and “abnormal” in something as important to the autistic community as the diagnostic criteria is extremely harmful. It sends the message to an autistic person that they are not good enough and that their brains are lacking what is needed to fit in or be ‘normal’. This will inevitably lead to masking and a negative self view, which has a significant negative impact on mental health. The neurotypical world has begun accepting different kinds of people, shifting away from the use of the term ‘normal’. Now we need to accept the neurodivergent community in the same way, and not compare them to a made-up concept.

Autistic People are not the Issue: the Importance of the Double Empathy Problem

Autistic people are constantly told that they are the problem. It is almost like their brain is inconvenient to the rest of society. They are told that they are the ones with social difficulties and deficits in communication. However, what if this was not actually the case? Autistic researcher Jac den Houting claims that their autism diagnosis was the best thing that had ever happened to them, and upon researching the diagnosis was surprised to learn that what had been so important and positive for them (their autism), was perceived as something negative in the medical model (Den Houting). Perhaps the neurotypical community is equally responsible for the communication ‘challenges’ that autistic people face. Maybe there is an invisible barrier between the two communication methods, and only through breaking the barrier is it possible to have clear communication across neurotypes. These questions are all addressed through a paradigm shift called the double empathy problem. The double empathy problem, a term coined by autistic autism researcher Damian Milton in 2012, suggests that it is neither autistic people nor neurotypical people that have difficulties communicating. Instead, it is the mismatch between the neurotypes that makes communicating with autistic people seem challenging (Milton, 883-887). This shifts the paradigm from the deficit model (i.e., assuming that autistic people have deficiencies) to a model emphasizing mutual communication. A few experiments have been done to test this theory using both autistic and non-autistic people.

The telephone experiment

A study conducted by Crompton and colleagues tested the idea of the double empathy problem in a game of telephone (1707). In total, nine groups of eight people were arranged. Three of the groups contained only autistic people. Three groups were made up of only non-autistic people. The last three groups were made up of a mix between autistic and

non-autistic people, alternating (Fig. 1). The researchers shared a story with one person in each group and asked them to impart the story on another member of the group until everybody in the group had heard the story. After each game of telephone, it was found that the groups made up of people with the same neurotype (i.e., only autistic and only non-autistic people) shared information equally as well. However the groups consisting of people with mixed neurotypes had significantly lower rates of information sharing. Additionally, members of the mixed group rated people of the opposite neurotype lower on measures of rapport than members of the same neurotype. This finding would support the hypothesis of the double empathy problem, as communication was clearly more difficult for the mixed neurotype groups than it was for the same neurotype groups. This would provide reason to believe that autistic people better understand other autistic people and the same for non-autistic people.

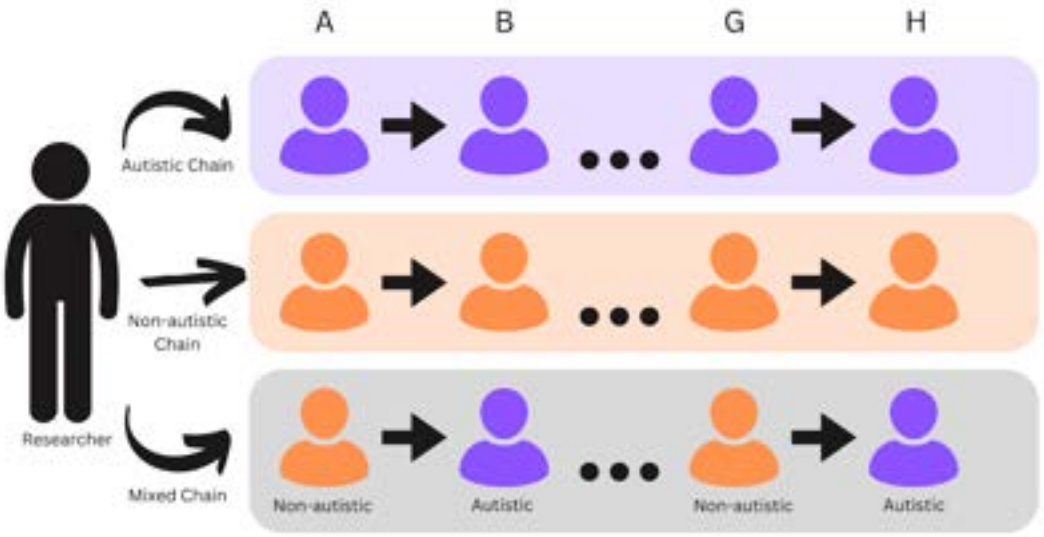

Figure 1. Depiction of diffusion chain method. Visual representation of diffusion chain experiment conducted by a researcher where only autistic people, only non-autistic people, and a mix of both autistic and non-autistic people shared a story in a game of telephone. Adapted from Crompton et al. 1706.

Interpretation of autistic people

A few studies by various researchers were conducted to test the perception of autistic people by neurotypical counterparts. In a study by Sasson and colleagues, a video was taken of a 60-second practice audition performed by autistic and non-autistic people for a reality/game show (2). The audition was judged by non-autistic viewers. The clips were shown to viewers with the following modifications: (1) audio-only, (2) visual-only, (3) audio-visual, (4) static image, and (5) transcript of speech content. The viewers were not informed that some auditioners were autistic, but when asked to rate the favorability of the auditioners, non-autistic people were rated more highly than autistic people. However, when asked to rate the favorability of the transcripts of both groups, no one group came out on top. This suggests that it is the outward

behaviors of autistic people that causes them to be discriminated against by their neurotypical peers upon first impression, not the content of their speech (Sasson et al. 7). This finding would be in line with the ideas of the double empathy problem. As a species, humans prefer people with similar traits and behaviors to their own (Seidman).

Nevertheless, there are studies that could contradict the hypothesis of the double empathy problem. Although studies like the one conducted by Crompton and colleagues would provide a basis to believe that autistic people favor other autistic people, a study by Grossman and colleagues wanted to see if the autistic people would innately favor other autistic people, without the explicit disclosure of a diagnosis (846). In the study, teenagers with and without autism were asked to watch short video clips of autistic and non-autistic people. It was found that both groups spent less time looking at the videos of autistic people. Furthermore, the videos of autistic people were judged more negatively than non-autistic people's videos by both autistic and non-autistic people. Given the ideas of the double empathy problem, it would have been assumed that autistic people would judge fellow autistic people's videos more highly than the non-autistic people. However, the double empathy problem proposes that the difficulties in communication are caused by a mismatch of neurotypes, whereas this study focused merely on initial impressions. Moreover, an argument could be made to describe the reasons why this first impression does not follow what would be expected considering the double empathy problem. Many autistic people tend to mask their true selves in social situations, becoming more 'neurotypical' to better assimilate into the neurotypical culture of their surroundings (National Autistic Society). This would propose a positive association between the behaviors of neurotypical people, and the behaviors autistic individuals wish to emulate within themselves. Although masking uses a lot of energy for the autistic person, this process often happens innately. For this reason, it would make sense that autistic people prefer the social interaction capabilities of neurotypical people, because society has made those behaviors seem like they are the most desirable and acceptable. If society normalized the idea that there is no normal, it would be intriguing to redo the study and see if the findings differ.

The harm of masking and its significance to the double empathy problem

As mentioned previously, the process of masking is extremely detrimental to the mental health of autistic people (Mitchell et al. 10). Not only does masking occur because autistic people feel as though they are not accepted the way they are, but it can lead to loneliness despite the apparent presence of a social community (Mitchell et al. 10). The feeling of loneliness is unfortunately a very common sensation experienced by the autistic community. As a young child, especially if ASD has gone unnoticed or undiagnosed, social interactions can be quite difficult and the differences in behavior of autistic people lead to a lack of understanding by their peers (Neff). Given that humans have an innate desire to be a part of a community (Cohen), autistic people mask their true behaviors to be included in social groups. This masking occurs in part as a result of the double empathy problem and the mismatch of communication styles between autistic and non-autistic groups. Despite the apparent success of this strategy, the feeling

of loneliness can persist. This may be due to the fact that through masking, autistic people never show their true selves, which means who they really are is never accepted by their peers. Autistic people are of the opinion, and evidence from studies like Sasson and colleagues agrees with this, that unveiling their real personalities will lead to their exclusion from society (7). This further exacerbates the need for change in society. Without more understanding of what being autistic means, more places where autistic people can feel safe, and a communication type that both the autistic and non-autistic communities can understand, this feeling of loneliness will continue, and can lead to severe manifestations of anxiety and depression.

Social model of disability

One other important concept associated with autism and the double empathy problem is something called the social model of disability. This model discusses the difference between a disability being something caused by oneself versus a disability being caused by the environment. This model opposes the traditional medical model approach to a disability, which posits that a disability is within the individual and its associated challenges are not 'normal', thus needing to be cured or fixed. Instead, the social model of disability places the blame for a person having difficulties in their life on the environment (Buder and Perry). Consider the following example: a person in a wheelchair needs to use an elevator to go up to a higher floor, but the building does not have an elevator. The medical model would consider this a problem within the person in the wheelchair, as they are the one who cannot walk. On the other hand, the social model of disability would consider this a problem with the environment.The person in the wheelchair is unable to reach their goals because they are disabled by their environment, not the other way around. This concept can also be applied to the double empathy problem. Looking at autism from the perspective of the social model of disability allows us to look through a different lens. The more we take the blame off of autistic individuals for the difficulties they face, the more society will come to learn about what being autistic really means and the importance of trying to understand a variety of neurotypes. It would alleviate a significant amount of mental health issues for autistic people, if we start looking to help them by changing their environment, not forcing change upon them.

Conclusion

It is time to flip the narrative. Autistic people have advocated for themselves, but their voices are subdued by the allegedly more knowledgeable voices of the population educated in the medical model, telling autistic people and the general public what treatments they need to become 'more normal' and how they should behave to be accepted socially. If there was no preexisting idea of 'normal', autistic people would not be ostracized for their 'abnormal' tendencies. If autistic people were given more input into their treatment and could become self-advocates, perhaps they would be more pleased by the outcome and have less mental health challenges. And maybe if society accepted autistic people the way they were, there would be no need for treatment, just changes to their environment. As the social model of disability explains, the environment disables the person, not the other way around. If this is the case, then it is

necessary to change the environment and make it a place more open to accepting autistic individuals. While a portion of changing the environment relies on the ability of the autistic person to self advocate by stating their accommodation needs, the majority of the responsibility to change the environment is in the hands of the non-autistic community. If society does not fully understand autistic people and still considers them all Rain Man, the autistic community will hardly get anywhere when self advocating. For this reason, autistic people need more opportunities to share their real experiences and thereby gain sympathy from the non-autistic population. It is the latter population's sympathy that will lead to environment shifts large enough to positively impact the success rate of autistic people in society.

It is time we shift the paradigm and redefine autism. Autism is not something negative or abnormal as explained by the deficit model, but instead is something beautiful and necessary to the diversity of the planet. If each person changes just the way they think about autism and neurodivergence in general, it will make an immense difference. More autistic people would be given multimodal communication opportunities, because being communicative is more important than being able to talk. ABA would not be the first step in helping an autistic person. Instead, changes to their environment could make an autistic individual feel seen, heard, and confident in their ability to succeed. Autism would not need to be diagnosed using criteria based on how 'normal' someone is. A new understanding of autism could make different criteria for different genders and age groups, using positive language that does not impact the self esteem of the autistic population. At some point, maybe there would not even be a need for a diagnosis, because people would just be accepted as they are without an obligation to justify accommodations. Most importantly, by recognizing that many of the difficulties autistic people face are caused by the environment, autistic people would struggle less mentally, and learn that they do not need to mask themselves to be accepted. Society needs to accept them for who they are.

Neurodivergence is a social construct, and one that we no longer have to abide by. There is no neurotypical or neurodivergent, because if there is no 'typical,' then there is no 'divergent.' By letting autistic people be themselves, without labels, and supporting them in any way possible, we are validating their humanity and sending the message that everyone, no matter who they are or how their brain works, is welcomed as an equal in society.

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Why do individuals with familial Alzheimer's disease experience symptoms of depression and other behavioural changes in early adulthood, and is there a connection between these manifestations and BDNF Val66Met mutations or early Alzheimer's pathology? By Jad Hijazi

Alzheimer's disease (AD) is a complex neurodegenerative disorder characterized by the aggregation of amyloid-β and the development and spread of hyperphosphorylated tau, leading to neuronal and synaptic loss. The resulting pathological cascade initially manifests as cognitive impairment, which progressively escalates to dementia. While significant progress has been made in understanding the molecular underpinnings of AD, there is insufficient research to understand the clinical pathological relationships better.

Alzheimer's disease exists in both sporadic and familial forms. Sporadic AD, the more common type, occurs without a clear genetic link and typically manifests later in life. Some risk factors, for example, are smoking, cardiovascular disease, and cortical thickness (Chakrabarti et al., 2015). The differences between sporadic and FAD highlight the diverse factors contributing to the disease and underscore the importance of investigating both forms to understand the complexities of Alzheimer's pathology comprehensively.

In an attempt to identify universal biomarkers of Alzheimer's pathology, recent research has explored the role of neurotrophic factors, such as brain-derived neurotrophic factor (BDNF), in moderating the neuronal and synaptic dysfunction associated with AD (Fumagalli et al., 2005). Neurotrophic factors play a crucial role in promoting the survival, development, and function of neurons. Evidence suggests that reduced levels of BDNF may contribute to the synaptic and cognitive impairments observed in AD (Girotra et al., 2021).

Understanding changes in these genetic factors is crucial in unraveling the complexities of neurodegenerative diseases, including FAD. Familial Alzheimer's disease is a hereditary form of the condition, accounting for a small percentage of all Alzheimer's cases (Feldman et al., 1963). It is associated with mutations in specific genes, such as presenilin 1 (PSEN1), presenilin 2 (PSEN2), and amyloid precursor protein (APP) (Ibanez et., al 2021). Investigating polymorphisms in neurotrophic factor genes that impact key markers like tau and amyloid-β becomes particularly significant when exploring the genetic underpinnings of familial Alzheimer's disease.

Current research not only enhances our understanding of the intricate mechanisms involved in the disease's progression but also offers potential targets for therapeutic interventions aimed at halting or slowing down the neurodegenerative process in individuals with a familial predisposition to Alzheimer's. Identification of disease-modifying genetic factors could offer novel therapeutic targets to mitigate the neurodegenerative processes in both sporadic and familial forms of the disease (Cao et al., 2018). Furthermore, recognizing and addressing the various risk factors associated with Alzheimer's, such as age, family history, and certain lifestyle choices, are crucial in developing comprehensive strategies for prevention and intervention. By comprehensively understanding the genetic and environmental factors

contributing to Alzheimer's disease, we can take significant strides towards more effective and personalized approaches to manage and potentially prevent this debilitating condition.

The Impact of BDNF mutations on Alzheimer's disease:

Under normal conditions, BDNF, a crucial neurotrophic factor, is pivotal in moderating neuronal growth and function. It is involved in synaptic plasticity, repair throughout the lifespan, and is expressed prominently in the hippocampus, where it is essential for long-term potentiation (LTP) underlying hippocampus-related memory. However, in Alzheimer's, BDNF, particularly the BDNF Val66Met polymorphism takes on a distinctive role: characterized by a missense change (G196A) resulting in a Valine to Methionine substitution at position 66, has been a subject of increased attention (Giarratana et al., 2019). The BDNF Val66Met polymorphism leads to reduced dendritic trafficking and synaptic localization of BDNF, causing up to a 30% reduction in activity-dependent BDNF secretion (Shen et al., 2017). In healthy young adults, carriers of the Met66 allele exhibit reduced memory-dependent hippocampal activity (Brown et al., 2020). Given the relatively high prevalence of BDNF Val66Met, ranging from 29% in European to 72% in Asian countries, this polymorphism may constitute a genetic factor that modifies functional brain alterations in a substantial portion of AD subjects.

Current clinical studies face limitations in investigating BDNF due to the absence of validated biomarkers for central nervous system BDNF. Issues with validating biomarkers for BDNF arise from its complex role in various biological processes and the challenges in accurately measuring its levels in the brain. Examples of previous biomarkers for Alzheimer's disease include amyloid-β and tau levels in cerebrospinal fluid (Honea et al., 2013). Recent studies in sporadic Alzheimer's disease's preclinical stages indicate that Met66 carriers experience increased rates of episodic memory decline and hippocampal atrophy compared to Val66 homozygotes. Notably, cortical amyloid-β accumulation appears unaffected by the Met66 allele, suggesting that BDNF Met66 may accelerate neuronal dysfunction and memory decline through processes downstream of amyloid-β accumulation, such as tau aggregation (Miranda et al., 2019).

With a mean onset age of 45 years, FAD provides a unique context for investigating the effects of the BDNF Met66 allele on episodic memory, hippocampal function, amyloid-β, and tau (Lim et al., 2016). The primary hypotheses posit that preclinical FAD mutation carriers with at least one copy of the BDNF Met66 allele would exhibit greater episodic memory and hippocampal function impairment than Val66 homozygotes. Elevated CSF tau levels, particularly the regular
(non-hyperphosphorylated) form, are implicated in Alzheimer's disease pathology and contribute to cognitive deficits. Beyond these primary hypotheses, Lim’s study delves into the exploration of the association between the BDNF Met66 allele and various cognitive domains, neuronal function in the precuneus, and CSF biomarkers of amyloid-β1-42 and phosphorylated tau (p-tau181) (Lim et al., 2016).

Furthermore, the potential additive effects of the BDNF Met66 and apolipoprotein E (APOE) ε4 alleles on amyloid-β-related cognitive decline, given such effects in preclinical

sporadic Alzheimer's disease. In conclusion, Lim's 2016 study seeks to unravel the nuanced effects of BDNF Val66Met in the context of FAD, shedding light on its impact on diverse cognitive domains and neuropathological markers.

Changes in Cortical Structure and Functional Connectivity from the BDNF Val66Met mutation:

While neuroimaging studies have shown small BDNF Val66Met effects on hippocampal volume, there is growing evidence of BDNF Val66Met-related reductions in hippocampal FDG-PET metabolism and stronger memory impairment in both FAD and sporadic AD. This suggests that BDNF Val66Met may particularly influence the impact of AD pathology on hippocampal function and memory.

Resting-state functional MRI studies, which examine brain activity while individuals are not engaged in any specific tasks, have emerged as valuable tools in understanding the neurobiological changes associated with Alzheimer's disease (AD). These studies consistently reveal alterations in the connectivity patterns of the hippocampus, a brain region crucial for memory formation and retrieval, with key regions of functional networks implicated in AD pathology, such as the default-mode network (DMN). The DMN is a network of brain regions that are active when an individual is not focused on the external environment and is instead engaged in internal thoughts, self-reflection, and memory consolidation. Reduced connectivity between the hippocampus and DMN regions suggests disrupted communication within brain networks crucial for memory processes, contributing to the cognitive decline observed in AD. This alteration in connectivity patterns provides insights into the underlying neurobiological mechanisms of memory impairment in AD and underscores the importance of understanding network-level changes in the brain's functional architecture in neurodegenerative diseases (Sheline et al., 2013).

Current research addresses whether BDNF Val66Met moderates the impact of AD pathology on functional connectivity within major networks, including the hippocampal network, DMN, dorsal attention (DAN), salience (SAL), and fronto-parietal control (CON) networks. The choice of FAD subjects in the discovery sample allows for an examination of the effect of BDNFVal66Met on connectivity changes in genetically caused AD, minimizing confounding factors related to aging-related comorbidities.

In humans, possession of the Met allele has been associated with reduced grey matter in areas of the mid-frontal regions of the brain, fusiform gyrus, amygdala, and thalamus (Brown et al., 2020).

Neuroimaging findings reveal that older individuals with a BDNF Met allele experience decreased hippocampal activation when completing memory tasks, particularly during the encoding process, relative to that of Val homozygotes (Brown et al., 2020). White brain matter, specifically the posterior of the corpus callosum, also feature a significant interaction effect of age and the BDNF Val66Met polymorphism, with older Met carriers possessing a less dense structure (Brown et al., 2020).

Impact of the BDNF Val66Met Mutation on Behavioural disturbances in AD: 6

The intricate interplay between genetics and early manifestations of familial Alzheimer's disease in individuals during early adulthood has become a focal point of investigation. Specifically, there is a growing interest in understanding why individuals with familial Alzheimer's disease experience symptoms of depression and other behavioural changes during this early stage (Bekris et al., 2010). Moreover, researchers aim to uncover whether there is a connection between these manifestations and genetic predisposition or early Alzheimer's pathology. In this context, the BDNF Val66Met gene polymorphism emerges as a key player in BNDF polymorphism, which could impact behaviour as a result of its effects on cognitive functions.

Depression is a common neuropsychiatric comorbidity of AD, affecting up to 50% of patients and associated with various detrimental consequences, including poorer quality of life, greater disability in daily activities, faster cognitive decline, and increased burden on caregivers (Burke et al., 2019).

Researchers found that AD patients underwent clinical and neuropsychological examinations, as well as evaluations of behavioural and psychiatric disturbances. Patients were divided into two subgroups based on the presence (AD-D) or absence (AD-nD) of depression, according to DSM-IV criteria. The BDNF Val66Met functional polymorphism and apolipoprotein E (APOE) genotype were evaluated in each subject (Honea et al., 2013). Understanding the impact of the BDNF Val66Met polymorphism and APOE genotype in the context of Alzheimer's disease provides valuable insights into the intricate interplay between genetic factors and the manifestation of clinical and behavioural symptoms. These genetic variations not only contribute to the heterogeneity of Alzheimer's disease but also offer potential targets for further research aimed at elucidating the underlying mechanisms and developing targeted therapeutic interventions tailored to individual genetic profiles.

The results indicated that 35.2% of patients reported AD-related depressive symptoms. When compared to patients bearing no polymorphisms (BDNF G/G), BDNF G/A carriers showed more than a twofold risk, and BDNF A/A carriers had a threefold risk for depression in AD. The allele frequencies showed that the BDNF A allele was significantly over-represented in AD-D compared to AD-nD. An association between the number of carried A alleles and the severity of depressive symptoms was observed.

Current research points to how the role of BDNF genetic variation in the susceptibility to AD-related depression. The study highlights the importance of considering genetic background for better defining individualized risk profiles in AD.

Similarly, the cAMP signaling pathway plays a crucial role in mood regulation, and abnormalities in this pathway have been implicated in major depressive disorder (MDD) (Duman et al., 1997). A study aimed to investigate whether the diagnosis of a mood disorder or treatment with an antidepressant was associated with changes in hippocampal BDNF in postmortem brain samples obtained from the Stanley Foundation Neuropathology Consortium (Chen et al., 2001).

The results revealed increased BDNF expression in the dentate gyrus, hilus, and

supragranular regions in subjects treated with antidepressant medications at the time of death, compared with antidepressant-untreated subjects. Moreover, there was a trend toward increased BDNF expression in hilar and supragranular regions in depressed subjects treated with antidepressants, compared with those not on these medications at the time of death. These findings are in line with the broader context of the cAMP pathway and its downstream targets, such as BDNF, being implicated in the pathophysiology and treatment of MDD (Duman et al., 1997). The observed alterations in the cAMP pathway, including changes in CREB levels, as indicated by postmortem brain studies of MDD, reinforce the notion that abnormalities in cell signaling pathways contribute to the development of mood disorders (Cowburn et al., 1994; Dowlatshahi et al., 1999; Dowlatshahi et al., 1998; Lowther et al., 1997). Antidepressant treatment and electroconvulsive shock (ECS) have consistently been shown to upregulate components of the cAMP pathway in rodent brains, including CREB and phosphorylated CREB levels (Chen et al., 2001). Additionally, subsequent elements of the cAMP pathway, like BDNF, have been demonstrated to elevate following antidepressant treatment in the cerebral cortex and hippocampus (Fujimaki et al, 2000, Nibuya et.al, 1995).

Present studies, like Hui Yu's in 2010, provide a valuable link between these preclinical findings and observations in human postmortem brain samples, specifically in the hippocampus. The increased hippocampal BDNF immunoreactivity in subjects treated with antidepressant medications supports the idea that BDNF may be a crucial player in the therapeutic effects of antidepressants. This finding is consistent with previous reports of decreased CREB in the cerebral cortex of subjects with MDD, restored by antidepressant treatment, and increased levels of trkB mRNA associated with antidepressant treatment (Yu & Chen et al., 2010).

The focus on the hippocampus is particularly relevant, given the hippocampus's well-established role in mood regulation and cognitive processes. The dentate gyrus, in particular, is implicated in adult neurogenesis, which has been linked to antidepressant effects. The observed changes in BDNF expression in the dentate gyrus and other hippocampal regions further support the intricate relationship between antidepressant treatment and neurotrophic factors in key brain regions involved in mood regulation.

In conclusion, the study on increased hippocampal BDNF immunoreactivity in subjects treated with antidepressant medication provides crucial insights into the molecular mechanisms associated with antidepressant treatment in human postmortem brain samples. The findings align with the broader understanding of the cAMP signaling pathway and BDNF in the context of mood disorders, emphasizing the potential role of BDNF as a mediator of antidepressant effects in the hippocampus. This bridge between preclinical and clinical observations contributes to our understanding of the neurobiological basis of mood disorders and their treatment.

Limitations of the BDNF Val66Met mutation as a Novel biomarker for Alzheimer's Disease:

A diverse and not always consistent range of findings regarding the impact of BDNF Val66Met on cognitive domains has been reported (Brown et al., 2020). Null and inverse findings regarding the cognitive implications of BDNF Val66Met variants have also been

reported. For example, an examination of BDNF Val66Met and performance across multiple cognitive domains in a sample of older Chinese men found no difference between Val/Val, Val/Met, or Met/Met groups (Brown et al., 2020). This study may, however, have been underpowered to detect the small effects that have been reported elsewhere (n = 161). In a longitudinal study of older adults, Met carriers performed more poorly on a task of executive function at study entry but did not exhibit a decline in performance, which was present in Val homozygotes, over the 10-year follow-up period (Brown et al., 2020). Enhanced executive function in Met carriers, particularly in inhibitory tasks, has also been reported. One study found this positive Met effect for executive functioning in a cohort with an average age of 79 but not in their second cohort with an average age of 64 (Brown et al., 2020). Consistent with what is found in young adults, BDNF Val or Met alleles' positive or negative effects on cognitive performance in older subjects may depend on the specific task requirements and goals (Brown et al., 2020).

Summary

Alzheimer's disease, whether familial or sporadic, is a multifaceted neurodegenerative disorder characterized by the intricate interplay of genetic and environmental factors. Through this extensive review of the impact of the BDNF Val66Met mutation and Alzheimer's disease onset and progression, it is apparent that while progress has been made in identifying the structural and functional impacts of the mutation in patients, gaps remain in our understanding of the weight this individual mutation has on Alzheimer's disease as a whole. The complexity of Alzheimer's pathology underscores the need for interdisciplinary approaches that integrate genetics, neurobiology, and clinical research to develop more effective diagnostic tools and targeted therapeutic interventions.

The exploration of FAD in individuals during early adulthood raises significant questions about the connections between genetic factors and the development of clinical and behavioural symptoms. The BDNF Val66Met polymorphism has been implicated in altering BDNF activity, synaptic plasticity, and memory function, presenting itself as a potential genetic factor contributing to functional brain alterations in a significant portion of Alzheimer's subjects.

Neuroimaging studies suggest variations in hippocampal metabolism and functional connectivity, the exact role and consistency of these effects in different cognitive domains remain subjects of ongoing research.

In the context of behavioural disturbances in AD, specifically depression, the BDNF Val66Met polymorphism has been found to increase the susceptibility of patients to developing symptoms of depression, emphasizing the impact of neurotrophic factors on cortical function, beyond repair and plasticity. Moreover, the study of the cAMP signaling pathway and its downstream targets, including BDNF, provides a bridge between preclinical and clinical observations, linking molecular mechanisms associated with antidepressant treatment in human postmortem brain samples. The increased hippocampal BDNF immunoreactivity in subjects treated with antidepressant medication supports the potential role of BDNF as a mediator of antidepressant effects in key brain regions involved in mood regulation.

In summary, the exploration of genetic and environmental influences on Alzheimer's disease, along with the scrutiny of specific genetic variations such as BDNF Val66Met, provides crucial insights into the multifaceted nature of the condition. These insights not only deepen our comprehension of Alzheimer's pathology but also lay the groundwork for tailored therapeutic strategies and personalized care for individuals with a familial susceptibility to the disease. Moving forward, ongoing research in this area promises to expand our understanding of neurodegenerative disorders and to enhance the quality of life for those impacted by Alzheimer's.

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Confronting Drug-Resistant HIV: Strategies for Global Action by Bach Vu

Abstract

The emergence of drug-resistant HIV strains is a growing concern, particularly in the context of antiretroviral therapy (ART). To combat this issue effectively, focusing on enhanced treatment strategies and the development of drug therapies with improved resistance profiles. To this end, a global effort is required to limit the spread of drug-resistant HIV strains. In this article, the current HIV treatments and methods to prevent resistance are discussed.

Introduction

Currently, 38 million people worldwide are living with the human immunodeficiency virus (HIV) [1]. Due to great advances in treatment and outreach, 28.7 million of those people receive treatment for HIV. While this is an outstanding achievement accomplished through the past two decades, there is still much to be accomplished to achieve the UNAIDS goal of providing testing and treatment to 95% of the HIV population. HIV affects low-income areas most due to their restricted access to prevention and treatment. It is found that HIV impacts households, communities, and the economic growth of nations. With other serious challenges facing many developing nations such as infectious disease, food insecurity, and global health, it is important for a global community to provide testing and treatment in these areas.

Human immunodeficiency virus (HIV) is a bloodborne pathogen that damages the immune system [2]. While there is no effective cure for HIV, with medical care, it could be controlled, providing patients with long, healthy lives, while preventing spread to their partners and community. In cases in which the patient is not treated, it could lead to acquired immunodeficiency syndrome (AIDS).

HIV infects cells such as helper T cells, macrophages, and dendritic cells. T helper cells ($CD4^+$ cells) play an important role in the adaptive immune system by aiding the activities of other immune cells releasing cytokinesis; a physical process of cell division[3]. HIV-induced pyroptosis of abortively infected T cells and apoptosis of uninfected bystander cells cause low levels of $CD4^+$ T cells in HIV patients. As a result of $CD4^+$ T cells decreasing below a critical level, cell-mediated immunity is lost, making the body more susceptible to infections leading to AIDS.

T helper cells ($CD4^+$ cells) play an important role in the adaptive immune system by aiding the activities of other immune cells releasing cytokinesis; a physical process of cell division[4]. Helper T Cells not only activate B cells to secrete antibodies and macrophages to destroy ingested microbes, but they also activate cytotoxic T cells to kill infected target cells and activate cytotoxic T cells to kill infected target cells. In this paper, HIV drug resistance and the potential ways to prevent the spread are discussed.

Current Treatments of HIV

Antiretroviral therapy (ART) is the most commonly used treatment for HIV[5]. The treatment essentially reduces the amount of HIV and helps the patient stay healthy. Patients with HIV should be treated as soon as possible as evidence shows that earlier treatment of HIV, regardless of CD4 count, leads to fewer complications and possibly deaths. ART uses a combination of drugs as standard care for HIV. There are several classes of HIV drugs doctors can use when prescribing ART. The most commonly prescribed classes include nucleoside reverse transcriptase inhibitors (NRTIs), Non-nucleoside reverse transcriptase inhibitors (NNRTIs), Non-nucleoside reverse transcriptase inhibitors (NNRTIs), Protease inhibitors (PIs), and Integrase strand transfer inhibitors (INSTIs). Both the NRTIs and NNRTIs act by blocking reverse transcriptase and preventing the virus from replicating its DNA but differ in the molecular design. PIs inhibit HIV protease, an essential viral enzyme for replication, hindering the virus from proliferating. However, while PIs can be included in an initial ART regime, they require pharmacokinetic enhancer, a medication that amplifies the impact of the drug on HIV. INSTIs prevent HIV replication by inhibiting HIV integrase, an enzyme essential for the virus to copy itself. HIV integrates its DNA into CD4 cells for replication, and INSTIs halt the enzyme responsible for this transfer. Other treatments include entry inhibitors, also known as CCR5s or chemokine coreceptor antagonists, obstruct a protein called CCR5 on CD4 cells' surface, which the virus requires for cell entry. Fusion inhibitors stop HIV from fusing with the cell membrane of CD4 cells, which keeps the virus out. These drugs are not the first choice for starting treatment; they are considered for patients with experience in treatment who need to switch their regimes. Lastly, Pharmacokinetic enhancers which improves the performance of other medicines by affecting how they break down other drugs, leading to higher levels of those drugs in the blood.

HIV medications are most commonly prescribed as combination therapies. The most prescribed ART therapy is Biktarvy, which is a combination of an INSTI, bictegravir, an NRTI, emtricitabine, and an NNRTI, tenofovir alafenamide.

Causes of Drug Resistant HIV

When the first HIV drugs were introduced, drug resistance evolved in nearly all treated individuals in the first 6 months of treatment, and sometimes within weeks[6]. However, triple drug therapies, introduced in 1995, were expected to prevent the evolution of drug resistance and subsequent treatment failure. The reason for this is because each of three drugs individually brings the expected number of viruses produced by a single infected cell below one, causing the viral population to shrink.

Over the past decade, there has been an increase in the use of ART treatment, which has saved the lives of tens of millions of people[6]. The increased use of HIV medicines has been accompanied by the emergence of HIV drug resistance. Changes in the genetic structure of HIV that affect the ability of medicines to block the replication of the virus is the cause for drug resistance. All retroviral drugs, including newer drug classes, are at risk of becoming partially or

fully inactive due to emergence of drug-resistant virus. If not prevented, drug resistance in HIV can make medicines less effective leading to higher incidence of HIV infections and health problems related to HIV that can cause death. Drug resistance can be found in some patients before treatment. This resistance can be transmitted at the time of infection or acquired during previous treatments. As many as 10% of adults who begin HIV treatment can have resistance to non-nucleoside reverse transcriptase inhibitors (NNRTIs). Pretreatment NNRTI resistance is up to 3 times more common in people with previous exposure to antiretroviral drugs.

This drug resistance is common in children under 18 months and those newly diagnosed with HIV[7]. Studies from 10 African countries between 2012 and 2020 found that almost half of infants newly diagnosed with HIV had this type of drug-resistant virus before starting treatment. Since NNRTI resistance is widespread globally, it's important to quickly switch to treatments recommended by the World Health Organization (WHO) that use dolutegravir-based treatments. Dolutegravir is in a class of medications called HIV integrase inhibitors. It works by decreasing the amount of HIV in your blood and increasing the number of immune cells that help fight infections in your body.

Methods to Prevent Spread of Drug Resistant HIV

A global effort is needed to address gaining instances of drug resistant HIV[8]. These efforts would include routine viral load monitoring, improving adherence to treatment, conducting drug resistance genotyping, and regimen switch to most effective antiretroviral drugs combinations. Additionally, new drugs to treat HIV should consider improved resistance profile, combination therapy, ease of treatment, and novel mechanism of action to ensure they remain free of gained HIV resistance.

Moreover, multi-drug therapies can sometimes fall short of preventing the evolution of resistance due to pathogen populations not experiencing all drugs in all places at all times[9]. To overcome this HIV combination therapies should be designed such that all drugs are effective, there is no cross-resistance, there is spatial heterogeneity in drug levels, and temporal heterogeneity in drug levels.

Conclusion

The global battle against HIV remains a multifaceted challenge, with significant progress achieved in providing antiretroviral therapy to millions of individuals living with the virus. Better antiretroviral therapies have drastically improved the lifespan of individuals living with HIV. However, the emergence of drug-resistant HIV strains poses a growing threat to the efficacy of treatment efforts. Such resistance can be present before treatment or acquired during previous treatments. To address the increasing threat of drug-resistant HIV, a global effort is imperative. The ultimate goal is to ensure that individuals living with HIV continue to receive effective treatment, minimizing the effects of the virus on their health and the transmission to others.

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Creating More Effective Influenza Vaccines by Ibrahim Chaudhry

Research question

How can vaccine development strategies be optimized to stay ahead of the rapid mutation rate of the influenza virus, and effectively address the challenges posed by their evolving nature?

Introduction

The influenza virus has imposed a significant burden on global public health for many years with its potential to cause major pandemics. Annually, the virus affects around 1 billion people worldwide, killing roughly 450,000 of them (World Health Organization 2023). A characteristic of this pathogen is its ability to undergo rapid genetic mutations, leading to the emergence of strains that challenge the effectiveness of existing vaccines. Each year, a new vaccine is administrated in attempt to keep up with the virus's rapid mutation rate. It is important to stay ahead of the influenza virus because it can be very contagious and sometimes fatal, especially in people who have not received the most recent vaccination. If scientists do not develop effective vaccines, pandemics may occur, and even a mild influenza pandemic can cost millions of lives and around 330 billion USD worldwide (Sidorenko and McKibbin 2006). This paper will delve into the current state of vaccine development, encompassing conventional influenza vaccines, advancements in vaccine design, and the integration of cutting-edge technologies and surveillance mechanisms to create a comprehensive response to the challenges posed by the influenza virus's dynamic evolution.

Current State of Vaccine Development

The battle against the influenza virus demands a continual evolution of vaccine development strategies to confront its rapid mutation rate and ever-changing nature effectively. Significant progress has been achieved in the field of influenza vaccine development, yielding valuable insights into the virus-host interactions and driving the quest for more effective and adaptable immunization approaches.

Reasons for Vaccine Obsolescence

When a virus enters the human body, it enters a target cell to use its machinery. Inside the cell, it makes contact with the plasma membrane and starts replicating by using host ribosomes to produce its proteins (Louten, 2016). Virus particles are created through this process and become infectious virions that are released from the cell to continue the process of infection.

Viruses undergo mutation, often as an evolutionary strategy, which may enhance adhesion to host surfaces, and avoid immune responses. Rates of mutation differ among viruses, depending on multiple factors, the most important being whether the virus consists of ribonucleic acid (RNA) or deoxyribonucleic acid (DNA) (Cann, 2012). RNA viruses mutate extremely fast, potentially a million times faster than their host organism (Duffy, 2018). In the case of the

influenza virus, an RNA virus, the virus mutates in two manners: antigenic drift and antigenic shift. Antigenic drift is a slower form of mutation that consists of small changes in a virus' hemagglutinin (HA) and neuraminidase (NA). HA and NA are surface proteins that are identified by the immune system as antigens, meaning they can cause an immune response that involves the production of antibodies (CDC, 2022). Antigenic shift, on the other hand, is a quick and sudden change that leads to new surface proteins in the virus. This process can create virus subtypes that can cause new infections.

When traditional influenza vaccines are administered, an inactive sample of the virus is mixed with other ingredients and given as a dosage. These ingredients include formaldehyde to inactivate the virus, aluminum salts to enhance immune response, gelatin as a stabilizer, and antibiotics to prevent bacterial growth (Kalarikkal & Jaishankar, 2023). When administered, the vaccine has the same physical features as the real virus without the ability to replicate and become virulent. When the vaccine enters the body, helper T-cells activate B-cells to create antibodies that fit the inactivated virus's surface proteins (Alberts et al., 2002). Additionally, cytotoxic T-cells are activated to kill cells that were introduced to the inactivated virus. (Charles A Janeway et al., 2001). After this, memory cells (clones of the cells used to fight the pathogen) are created in case another infection occurs. The issue is that this pathogen may mutate enough that its surface proteins become unrecognizable to memory cells and the body is required to start a new immune response against a mutated version of the former virus (Palmer et al., 2016). In this case, a new vaccine is required to combat the newly mutated virus.

Creating More Effective Vaccines

Scientists have discovered a few factors that can be altered to aid their pursuit of a universal influenza vaccine that can provide long-lasting protection against multiple strains of influenza. These factors include adjuvants, vaccine platforms, antibodies, pathways, and delivery methods.

Adjuvanted influenza vaccines are a widely used method to combat the virus that includes typical vaccine ingredients along with an added ingredient in hopes of improving efficacy

(Tregoning, Russell, and Kinnear 2018). So far, six different adjuvants have been legally used in human trials: AS03, AF03, and MF59 (oil-in-water emulsion adjuvants), along with alum, heat-labile enterotoxin (from E. coli), and virosomes (an artificial virus). These adjuvants have been mostly well-received, but there have been a few cases in which they are less effective than vaccines without adjuvants, such as heat-labile enterotoxin in patients with Bell's Palsy. While adjuvants cannot single-handedly create universal vaccines, they have proven to aid vaccine efficacy and will likely be a key component in future influenza vaccines.
The COVID-19 pandemic led to the testing of numerous different vaccine platforms. Scientists found that messenger RNA (mRNA), which played a crucial role in creating COVID-19 vaccines, could allow for faster production of more potent influenza vaccines (Pfizer 2022). The current production of influenza vaccines takes multiple months, but the use of mRNA vaccines

could drastically shorten this process, allowing for the vaccine to be produced nearer to flu season so it can be more similar to active strains (Libbi Green 2023). While the mRNA influenza vaccine seems promising, its effect on efficacy is still an active area of research.

Antibodies are very common in influenza vaccines, but they are often only effective against singular strains of influenza virus. In recent years, scientists have begun using new antibodies that are effective against a wide variety of influenza viruses (Laursen and Wilson 2013). A common theme of these antibodies is that they target HA, an important surface protein in many influenza viruses. These HA-targeting antibodies have become a key component in wide-ranging influenza vaccines.

Lastly, the methods of influenza vaccine administration have proven to play an impactful role in efficacy. The two most common delivery methods are injection and nasal spray. The injection is known as an inactivated influenza vaccine (IIV) and the nasal spray is known as a live attenuated influenza vaccine (LAIV) (Hoft et al. 2017). Studies have shown that LAIV, a live, but weakened form of the influenza virus grants more protection in children aged 6 months to 18 years than IIV. However, it was also found that LAIV granted either equal or less protection to those who had previous contact with influenza. Additionally, LAIV mimics natural influenza, causing it to be more effective at prompting T-cell responses. It can be taken away that the IIV injection is more effective in adults who had previously been infected with influenza and LAIV is more effective in healthy children with no prior contact with influenza.

Conclusion

In conclusion, the influenza virus can be detrimental to global health and the economy, so it is important to stay ahead of its rapid mutation rate. While it is an extremely difficult and long process to formulate influenza vaccines, scientists have made numerous discoveries to aid their quest for an effective universal vaccine. These discoveries include ingredients used in vaccines alongside different methods of administration. Although the “perfect” universal influenza vaccine is yet to be created, it seems that in the following years, we will see major improvements in the vaccine.

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Mind and consciousness - is materialism true?

Exploring theories about the mind-body problem and evidence for the non-physical

Index

Introduction/synopsis/abstract

This paper investigates the various theories that try to explain consciousness using empirical evidence. Every theory mentioned in this research paper is provided with criticism and proof.

The aim is not to select the most probable theory that fits our empirical view of the universe but to prove the existence of the non-physical. The predominant view regarding consciousness is that it originates wholly through natural means. I aim to take the other under-represented perspective in this paper and view it through the lens of the scientific method. It goes without saying that if the aim is to discuss consciousness through the other perspective, we must first talk about the perspective we're countering. Hence, this paper's first part, Part I, discusses materialism. Having said that, I aim to write a paper that is as unbiased as possible. If there is truly no evidence to support the other side of the spectrum, I would not be writing this paper. Part **II** proposes solutions to the mind-body problem that are not materialism. Part **III** of this paper goes into evidence for a non-physical reality. This evidence talks about NDEs, their proposed materialistic explanations and the criticisms of these explanations. Then, I handpicked three strong NDE cases that I believe show empirical evidence for the persistence of consciousness beyond death (At least for a short period). I have also added less medically verifiable anecdotal NDEs in this paper to support the major 3. I have also commented on the lack of clarity about what precisely this persistence is or for how long it exists. Then, I talk about paradoxical lucidity with a focus on terminal lucidity. To me, paradoxical lucidity is just supplementary proof to NDEs and is not a strong argument for the non-physical alone. This is not to discredit paradoxical lucidity, as the experience itself is more straightforward to explain and suggests the non-physical as soon as one hears of this experience and that it is a scientifically accepted experience. However, as of 2024, terminal lucidity is not considered a medical term, and there is no official consensus on the identifying characteristics. There is no doubt, however, that this phenomenon does exist, as there are well-documented cases of it occurring. The paper then finally concludes with a beautiful quote that Dr Bruce Greyson said was said by one of the people who had an NDE and tried to explain it, and my final thoughts on NDEs and terminal lucidity.

Materialism

Materialism falls into a school of thought called "substance monism." Substance monism is the belief that all existing things can be reduced to changes in one singular substance and that the "one singular substance" is the only fundamental thing. Thales of Miletus (sometimes called the first philosopher) believed in substance monism. He believed that "water" is the only ingredient for all that exists. When we talk about materialism, the fundamental substance that we talk about is "matter."

Materialism asserts that all things, mind, consciousness, space, and sometimes even time, can all be reduced to the fundamental substance called "matter". There are many types of materialism, and many schools of thought related to materialism—eliminativism, non-reductionism, etc. For this paper, and in reality, the one thing that these schools of thought mostly always agree on is that the physical is all that exists and that the supernatural need not be invoked.

Thankfully, attacking this one core belief is all that matters for this paper. The purpose is to show that matter may not be the only core substance, mind may not "emerge" completely from matter, and that there may exist the supernatural. In essence, if we can show that there needs to be an explanation greater than matter for consciousness, we've established our purpose.

Criticisms and Support for Materialism

The most common support for materialism is that when the brain is under anaesthesia or when certain parts of the brain are damaged, consciousness doesn't precisely "function" like it usually does, making the argument that consciousness is, thus, dependent upon the brain. The criticisms against this argument are many. The one that is usually cited is that - "just because consciousness is dependent upon the brain, does not mean that it is generated by it."

"Emergence" is sometimes given as an answer to how consciousness emerges. In essence, neurons firing in the brain form a complicated system that integrates into consciousness. In other words, smaller, less complex entities (neurons) combine to create a more difficult process (consciousness), and the more complicated process is much unlike its smaller processes. It is also noted that consciousness is referred to as an "emergent" and not a "Resultant" because consciousness is not the sum of neurons. It is a much more complicated process emerging from it. The argument against emergence and emergentism in the case of explaining how the mind works is that, so far, there has been no straightforward way of explaining how exactly these bunches of neurons generate consciousness. Another argument against emergence is that we have evidence that complexity doesn't generate consciousness. The evidence is artificial intelligence.

Another "proof" of materialism is Occam's Razor. One must ask oneself, "What is the simplest explanation?" What is the need for invoking the supernatural? That just creates more problems for us. Materialists often cite the argument of "God of the gaps", which means that humans have tended to explain things that we don't understand by saying that "God did it". Examples of this are lightning, earthquakes, etc. We used to say that God's anger caused earthquakes and lightning. The main principle of Occam's razor is that the theory that assumes the least is probably correct. Intuitively, this seems to be materialism. This is because materialism fits in like one of the final puzzle pieces to the puzzle we call science.
This argument is criticised for being more about why materialism should be true than about why it is true.

Another question that we must ask is, "Can materialism prove consciousness is generated in the brain, then?"
The first thought that comes to mind is that if we can prove the perspective of emergence in the theory of mind, as in establishing precisely how the neurons integrate to form the complex process of consciousness, then materialism can prove consciousness. Some may call this wishful

thinking. Instead, if we can replicate consciousness on a computer or artificial intelligence, materialism can be proved. This is because if consciousness is simple enough that humans can create it artificially, there is no need to invoke the supernatural to explain how it is made.

Conclusion

The proofs and intuitions for consciousness are satisfactory. Having said that, the criticisms against materialism also cannot be ignored. It is safe to say right now that materialism isn't scientifically verified. There are, however, a couple of ways by which it could be verified. For example, if we can make artificial intelligence conscious, it proves that there's nothing "non-physical" about consciousness. The argument that there's no need to believe in something other than the physical has intuitive appeal. Part **II** of this paper will try to disregard this and prove there is reason to believe in things other than the singular fundamental substance, matter.

What, then, is the correct solution to the mind-body problem?

Discussing the problems with materialism is easy. The problem comes when we try to discuss what the solution to consciousness should be if we reject materialism. I will discuss some of the proposed solutions, but this paper will focus on proving that there is reason to believe, in general, that there exists other than the physical; I will not single out precisely what.

Dualism

Dualism, technically speaking, refers to the belief that philosophical monism is not true and that there are two fundamental substances—mind and matter. Sometimes, however, it just means that mental phenomena are non-physical.

When discussing arguments for dualism, most people think of the "zombie argument" by David Chalmers. The zombie argument asks us to imagine p-zombies (philosophical zombies), molecule-to-molecule copies of a human being but do not have consciousness. These p-zombies are conceivable and, thus, are metaphysically possible. In order words, we can imagine a world where these p-zombies are the ones existing and not conscious human beings. Chalmers suggests that the simple fact that these creatures are metaphysically possible points to the fact that consciousness is non-physical. He means that if molecule-to-molecule copies of human beings that don't have consciousness can be made, then consciousness is added to these p-zombies after the construction of the zombies has been done to turn them into humans.

A common refutation of the zombie argument is that p-zombies are logically incoherent. What

this means is that if a molecule-to-molecule copy of humans was made, it would have consciousness. Hence, p-zombies are not metaphysically possible.

Idealism

Idealism is the belief that reality is constructed from a single substance called the "mind." It preaches that reality is a mental construct and that matter does not exist. This idea is preached throughout many religions. Divine idealism is an example of Idealism, which holds that everything exists inside God's mind and that there is no such thing as a mind-body problem. Three types of idealism are usually mentioned: ontological, epistemological, and absolute idealism. There are few supports and many criticisms for all three of these beliefs. For this paper, I will provide an intuitive appeal for idealism as a solution if materialism isn't true. No evidence for idealism can be counted as "scientific".
The intuitive appeal comes from the fact that idealism is, in essence, the hard opposite of materialism while still sticking to monism. If all that exists comes from a fundamental substance called matter, if this theory is not valid, why not say, "All that comes is from a fundamental substance called mind?"

This argument is criticised for not being proof at all. There are multiple logical thought experiments for idealism, but this paper is focused on trying to prove that something other than materialism is true. That is why going into these thought experiments would be a waste of time. This section of the paper presents some ideas proposed to solve the mind-body problem, some ideas that are not materialism. The next part of the paper is solely focused on the main objective of this paper.

Evidence for the non-physical?

This section of the paper will focus on two key aspects: NDEs (Near-Death Experiences), usually referred to as REDs (Recalled Death Experiences) in the NDE scientific field, and the phenomenon known as terminal lucidity.

NDEs (REDs)

Introduction

REDS are (allegedly) spiritual and profound experiences that have been reported by people often after being resuscitated after (but not limited to) cardiac arrest. In these experiences, people report seeing a tunnel of light, warmth, the feeling of being "home", euphoria, and other positive experiences. NDEs are not always positive, though. There are NDEs where people have reported seeing hell, car crashes, etc. NDEs are medically and scientifically verified to exist. The debate is

on the explanation of how NDEs happen.

The reason why NDEs are so believable is that these can occur when people are clinically dead. This means no electrical activity is going through the person's brain, and the brain is not receiving nutrients or oxygen. Dr Sam Parnia, on multiple occasions, has referred to this as not a play of words, but literally, in the true meaning of "literally" they are dead. Yet, they still produce lucid, "even more real than real" experiences. During recovery after cardiac arrests, there is a period of amnesia. NDErs still recount clear, vivid experiences of their NDEs even after this period of amnesia. There are cases of NDEs where people have, from a location apart from their physical bodies, accurately described their resuscitation. I have mentioned some of these cases in this paper. Then, there are NDEs where people who were born blind described seeing consistent with typical NDEs. There are NDEs where the NDErs have spoken information they possibly couldn't have known while in the NDE. For example, encountering people who were dead while the NDEr was having an NDE but could not have gotten the information that they were dead before the NDE. Then, there's also the fact that NDEs are cross-cultural. Multiple studies concluded that non-western NDEs are more similar to Western NDEs than dissimilar. I feel that the best way to prove the existence of the non-physical through NDEs is to target a specific type of NDE and write about the well-documented NDEs of that type. In my paper, I am targeting specifically OBE-type NDEs, where people leave their bodies and talk about information upon coming back that happened during the time of the NDEs that they couldn't have known (Veridical NDEs).
Ps- "NDEr" in this passage simply means someone who has had/is having an NDE.

Explanations and criticisms

There have been many explanations for NDEs that have been debunked.
This includes anoxia, a condition where the brain has little oxygen to no oxygen. It was proposed as an explanation for why NDEs occur. The thought process was that NDEs were a hallucination caused by anoxia. It was later debunked because it was proved that NDEs can occur even when there is a proper level of oxygen going to the brain.

Another explanation was Biochemicals like DMT are released in the brain and cause their hallucinative trippy effects, which have been reported to be similar to some NDEs. It was then proved that NDEs sometimes occur during clinical death. Clinical death is when neurons stop firing in the brain, the brain is not receiving oxygen or nutrients, and the cells begin to die. DMT, and even specific serotonin receptors that are responsible for hallucinogenic experiences, can not function without oxygen, nutrients and rapid cell depletion.

There are also explanations like "a burst of electrical activity in the first 30 seconds after cardiac arrest/death by cardiopulmonary criteria may cause NDEs." and "the so-called OBE sensation

may be an illusion caused by a dysfunction at the temporoparietal junction." (Quotes from a website mentioned in the bibliography)

Sam Parnia's peer-reviewed article in the QJM (Marked as *** in the bibliography) criticised this.

The first criticism stated that a rigorous study has yet to prove a causal relationship (or even a relationship to begin with) between NDEs and the "proposed physiological intermediaries."

Parnia also points out a bias. It is humans' inherent bias to associate experiences with ones that we have had before. Here, he pointed out that our bias to assume that any experience that even mildly is analogous to a hallucination is subconsciously deemed to be one before discussion of the experience even starts. We should keep this bias in mind when discussing NDEs.

The third criticism is that a study was conducted that showed that the brain waves in NDEs were processed similarly to memories of real-life events, unlike brain waves during hallucinations.

The problems

At least a hundred reasonable and rational models explain NDEs that aren't entirely debunked. These include but are not limited to the birth model, false memories, neuroatonomic models, etc. I cannot review all of them and their criticisms in this paper. However, I believe that some NDEs may defy explanation completely. I will mention some of them in this paper.

Another problem with NDEs is that the general masses listening to this story are usually either hardcore skeptic-scientists rejecting the experience due to previous experiences with illogical material or those who do not take research and evidence that seriously and are completely fine with accepting anecdotes like "the experiences in NDEs feel much more "real" than experiences during DMT." By saying this, I am not denying that they might feel more "real" than a DMT experience. I am not denying that NDEs may feel like they are there experiencing the NDE and controlling themselves in it. My point is that this is an anecdote and not "evidence" for or against an NDE.

Hence, we have to remember that we must consciously realise our biases. Hard skeptics must acknowledge NDEs and view them without a dismissive attitude. We must also be careful not to engage in wishful thinking because NDEs may provide proof for the non-physical and an afterlife. We must carefully note our biases and be as unbiased as possible when discussing this profound and awe-inspiring experience.

The NDEs that "defy explanation"

NDE of a retired Air Force pilot (marked as * in the glossary) By Dr. Michael Sabom Et al.

Notes for this NDE -
i) Clinically dead- this implies that the unconscious person cannot hear, see, or even process anything.
ii) The patient only knew that the researchers were interested in the NDE *after* he gave his account.
iii) This case is selected from Dr. Sabom's study and falls under the label of "unconscious before being brought into the OR and typically is unfamiliar with the personnel, equipment, or specific procedures used during surgery" (Quote from the article)

Summary - The patient is a retired Air Force pilot who is giving the recount of his NDE five years after it happened to Sabom
Evidences for the non-physical in this NDE -
a) correctly pointed out the defibrillator and its features and functions
b) Correctly described that the meter had two needles, one fixed and one which moved, and accurately described how it moved down to minute details

Notes - He could not have described the movements of the two needles down to the details like-

"The first time it went between one-third and one-half scale. And then they did it again, and this time it went up over one-half scale, and the third time it was about three-quarters. I think the fixed needle moved each time they punched the thing, and somebody was messing with it. And I think they moved the fixed needle and it stayed still while the other one moved up."

-Until and unless he had actually seen the two needles in movement. Also, in the words of Dr Sabom, "This charging procedure is only performed immediately prior to defibrillation, since once charged, this machine poses a serious electrical hazard unless it is correctly discharged in a very special manner."

Also, Dr Sabom stated that the meters described were not found in the newer Defibrillator models when the pilot was interviewed.

With all this evidence, we can safely rule out the possibility that the pilot faked his story or made it up on the spot. One thing that we must note is that the pilot told this story five years after the event. This is both positive and negative proof. One way to interpret it is that the effect of the NDE on the brain is clearly powerful, just like every other NDEr's brain. The other way is to say there was more time to fake his story; the latter is an improbable outcome, looking at the

evidence.

The only possible materialistic explanation for this ***ONE*** NDE is that the doctors at the surgery somehow contacted him and told him to say all of this. The doctors and surgeons were probably unaware of the phenomena of NDEs and were definitely unaware of Dr Sabom's study until it was completed.

Pam Reynold's case

Notes -
1) She was clinically declared dead
2) Claimed to have an OBE

Summary - Pam's **eyes were taped shut,** and she had **a very loud sound (100-decibel clicks and white noise masking in her ears and being under heavy anaesthetic) ticking in her ear throughout the entire surgery** through the use of earphones.
She was also under deep anaesthesia.

Despite this, Reynolds was able to recount the medical team's conversation accurately. She heard a female voice saying that the size of her veins was "too small" and that they needed to use other veins. She also heard the conversation about finding an appropriate artery to place an arterial line.

She was also able to accurately describe the Midas Rex bone saw, which she said looked like an "electric toothbrush." She could also describe a distinct "Natural D" note despite a very loud sound ticking in her ear.

Her medical team verified all these details. This means that all the conversations she recounted, the voices she heard of the medical team, and the descriptions of the Midas Rex bone saw descriptions were declared to be as accurate as what had actually occurred.

It should also be mentioned that Pam Reynolds was a singer and songwriter. Her profession as a musician is well-documented and widely acknowledged in discussions of her case.

One of the common materialist explanations for Pam's case is Anaesthesia awareness and the claim that she somehow had medical knowledge. Not only is there proof against anaesthesia awareness in this case ("She was under deep anaesthesia, which included a combination of barbiturates, hypothermia, and cardiopulmonary bypass. This level of anaesthesia is far deeper than typically associated with anaesthesia awareness." This quote is from Dr. Sabom's book "Light and Death: One Doctor's Fascinating Account of Near-Death Experiences," and at one

point, Pam Reynold's Body temperature was reduced to 50 degrees Fahrenheit to put her in a state of deep hypothermia during the surgical process. Research suggests that even if Patients are not as deeply cooled as Reynolds was, they do not exhibit signs of conscious awareness.), anaesthesia awareness doesn't even begin to explain the details that Reynolds was able to accurately describe because it is undebatable that she could not see and could not hear (refer *.* in bibliography or bold letters in the Pam Reynold's case)

The case of Al Sullivan

Notes - Not clinically dead; however, He was given a local anaesthetic for the insertion of an intra-aortic balloon (used to help the heart pump sufficient blood) and then a general anaesthetic for the surgery itself. This means he was fully unconscious during the critical parts of the operation. Thankfully, the main feature of this NDE occurs under general anaesthesia.

- addressing the claim of anaesthesia awareness under the general anaesthesia period, The depth of anaesthesia required for major heart surgery like a quadruple bypass is significant, making typical anaesthesia awareness (where a patient can hear and see specific details) highly unlikely.

- claimed veridical OBE NDE

Even if we account for the case where there is anaesthesia awareness (which there is no need to do here), in rare cases of anaesthesia awareness, patients might recall vague sounds or sensations but detailed visual or auditory perceptions like those described by Al Sullivan (mentioned below) are exceedingly rare and typically not observed under deep general anaesthesia like in this case and Pam's case.

Summary -

Mr Sullivan (a 56-year-old Van driver at the time of his NDE) had told his Cardiologist, Dr Anthony LaSala, about the experience shortly after he regained consciousness following the surgery. Apart from this, one of UVA's research papers (**^ in the bibliography) also stated that two important witnesses corroborated to them an unusual event seen by Mr. Sullivan during his NDE, and one of them also corroborated to them that Mr. Sullivan told him about the event shortly after it occurred.

Al is also behind a drape that blocks vision, and his eyes are taped shut.

The features -

Mr Takata (the cardiovascular surgeon) admitted to flapping his hands during surgeries (a unique

thing that he only does). Dr Takata could not confirm that he had flapped his elbows during Mr Sullivan's surgery in particular, but he did confirm that this is a regular habit. This is not so much a detriment to our case because the question of how he could know such a specific thing is essential to answer.

The next concern is that this flapping may have occurred when Mr Sullivan was under local anaesthesia. When Mr Sullivan was asked to expand on when he saw his arms flapping, he said that "he saw Dr Takata standing alone over his opened chest, which was being held open by metal clamps, and he also saw two other surgeons working over his leg. He recalls being puzzled at the time about why they were working on his leg when the problem was with his heart, but he now knows that at this point in the surgery, the surgeons were stripping the vein out of his leg to create the bypass graft for his heart." (A quote from the UVA paper)

A materialistic explanation for this NDE would require one to presume that Mr Sullivian(a 56-year-old Van driver) somehow had a premed level of knowledge (if we logically include the specific details of CABG knowledge), lied about being puzzled about "why they were working on his leg when the problem was with his heart", and lied about when the flapping had occurred and saw it during the local anaesthesia state. All these assumptions do not make sense, and I do not see the possible motivations.

However, the fact that a materialistic explanation is possible that says more than "everybody just lied", "Coincidences", or "Could hear when 100-decibel clicks and white noise are masking in her ears and being under heavy anaesthetic" for a veridical NDE, makes it weaker than the other two I mentioned above. That being said, the assumptions that must be made for the materialistic explanation are still too much and unverifiable, making this NDE a solid addition to our list.

Some other lesser verifiable cases

These cases are a bit weaker than the three mentioned above. There are multiple reasons why I say so, but some of the reasons are as follows -

1) These are anecdotes from one person; sometimes, others also vouch for this anecdote. However, this is weaker than an entire medical team verifying the "anecdote."

2) Time gap - Unlike the cases mentioned above, some cases I mention below will have a significant time gap (multiple decades) between the NDE occurring and the interviewer receiving the NDE.

3) Lack of proper review of medical documentation - Unlike the ones above, these cases don't have medical documentation proving the medical procedures that occurred during the NDEs.

4) Lack of skepticism due to being relatively unpopular and anecdotal - These cases don't get much attention from popular skeptic websites due to their anecdotal, unverifiable, and less evidence-based rigorous approach.

The Case of the Rev. L. J. Bertrand

Mr Bertrand was an experienced mountain climber. He was climbing the Titlis in the Alps when he had this veridical NDE. He reported it 30 years after it occurred when he sent a letter to William James on October 10, 1891. He was the group leader, but at one point, he was exhausted. Hence, he instructed his peers on how to reach the summit alone. These instructions were -
i) climb the peak on its left side and come down on its right side (there was a dangerous cut on the left)
ii) his strongest student was to take the position at the rope's end.
However, Mr. Bertrand started freezing to death and became drowsy. This is when he had this OBE. He noted -
i) the climbing party going up by the right side of the mountain
ii) the strong pupil who should've been at the end of the rope was neither at the beginning nor the end but away from it altogether.
Apart from this, he also saw -
i) The guide drank from Mr Bertrand's bottle of Madeira and ate a piece of Mr Bertrand's chicken.
ii) his wife, who had told him she would not be travelling until at least a day later, was coming to meet him in Lucerne with a party of four. Mr Bertrand saw them in a hotel that fell on the way from their home to Lucerne.

When the climbing party came back, they were able to rescue him. Mr Bertrand was able to infer from the reactions of his guide upon confrontation that they had gone up the right slope rather than the left, that two of the pupils had left their appointed places on the rope and that the guide had eaten some Mr Bertand's chicken and drank some of his Madeira. Mr Bertrand also confirmed (by confronting his wife) that his wife had set off for Lucerne with four travelling companions earlier than planned and that she had stayed at the hotel where Mr Bertrand had seen her.

The Red MGB

This is a veridical NDE, which is not an OBE. I stated that we would primarily focus on veridical OBE NDEs, but this is a compelling case by Dr. Greyson. This is a story about a person called Jack who was hospitalised in his mid-20s. There was a nurse who worked with him every day,

and the nurse was named Anita. One day, she told him that she would take the weekend off. While Anita was gone, he had a respiratory arrest in which he had an NDE. While in the NDE, he met Anita, who told Jack to tell her parents she was sorry that she had recked the RED MGB. Jack then woke up back in his body in his hospital bed. He told this story to the first nurse he saw as soon as he woke up from his NDE. It was then confirmed that her parents gave Anita a Red MGB for her birthday. It was also confirmed that she crashed into a telephone pole and died just a few hours before Jack's NDE.

The sauce on tie incident

This is another veridical OBE NDE. This was Dr Bruce Greyson's first-ever encounter with NDEs that got him interested in NDEs. This specific case happened to him just a few weeks into his training. There was a patient who had overdosed. The paper regarding this patient was shown to Dr Greyson when he was having his dinner. He was startled by this patient's case and ended up dropping his fork and spilling spaghetti sauce on his tie. He couldn't wipe it off, so he covered it with a lab coat so nobody could see it. He then went down to the patient's roommate and talked to her. He unbuttoned his coat there because he was sweating due to the lack of air conditioning in the 70s. The patient finally became conscious in the morning, and Dr Greyson decided to see her and introduce himself to her. This is when the patient stopped Greyson and said, "I know who you are. I remember you from last night." She then said that she saw Greyson talk to her roommate. She gave an accurate description of the conversation, along with where they were sitting while talking. She also went on to mention that Dr Greyson had a striped tie with a red stain on it. Dr. Greyson confirmed that the patient had not talked to her roommate since she came to the hospital and that she was the only one who saw the red stain.

The final <u>big</u> problem

Let us say that we accept this burden of proof and accept that materialism is false. NDE OBEs show us that the person truly was observing the operation from above. No part of the brain can somehow make our (acknowledging the lack of a better word) "soul" detach from our body and look at it from another perspective.

My point in saying all of this is that NDEs (and even terminal lucidity that I mention below) will never be **concrete** proof of the afterlife/before life. Recently, there has been scientific discourse about how much electrical activity goes on in the brain during clinical death. While there is a scientific consensus that the majority of electrical activity ceases, there is some evidence that some electrical activity, such as gamma waves, may still be observed temporarily even after the heart has stopped. This means that the brain is definitely not capable of overall function, but every sign of "life" has not disappeared at the point of clinical death, at least for a short while. The heart has stopped, the brain is not getting oxygen and nutrients, and the electrical activity

has also stopped, at least for the most part. It is to be noted that these gamma waves are very short-term and disappear quickly during clinical death (*. in Bibliography).

The implication is that clinical death is not the final stage of death, as there is evidence of some detected brain activity after the heart stops for a short while. Another fact to consider is that throughout our history when it was not possible to resuscitate someone from clinical death, it was considered the final stage of death. If someday we are able somehow to resurrect someone from brain death (complete, irreversible cessation of brain activity) and even biological death, those would not be the final stages of death, either.

Hence, the argument that one "came back from death and told his story" will never make sense because it forms an intuitive logical paradox. If someone is dead, how can they come back to life?

Hence, I believe that we should focus on veridical NDEs, try only to prove the existence of the non-physical, and not bother trying to figure out what this non-physical (the afterlife/before/consciousness) is.

Note- it should also be noted that death is a process and not a moment. For example, should the moment the heart stops beating really be considered clinical death, or should the moment the alleged gamma activity stops surging be called clinical death? I raise this point because the second the heart stops beating, consciousness and electrical activity don't instantly disappear and start dissipating, making death more of a process than a moment.

Terminal Lucidity

Terminal Lucidity is a subset of experiences called "paradoxical lucidity". Terminal lucidity is defined as an unexpected return of consciousness, lucidity, memory, and mental clarity shortly before death involving patients with severe psychiatric and neurological disorders. This differs from paradoxical lucidity as that is a bigger term that includes all experiences involving a return to mental clarity (after having psychiatric diseases).

There is no scientific consensus or even any satisfying explanations as to how Terminal lucidity and paradoxical lucidity occur.

It should be mentioned that only 6% of the paradoxical lucidity cases did the person live longer than a week. This is to say that 94% of the cases where the person has a return of mental clarity are cases where they die soon after. Hence, this is a majorly death-related phenomenon.

However, since there are documented cases of paradoxical lucidity (especially in Dr. Fenwick's

research) where people regain clarity for more than one week, it cannot be called entirely a deathbed phenomenon.

One of the best examples of paradoxical lucidity is the case of Anna Katharina Ehmer.

Anna was a 26-year-old woman. She had severe mental disabilities, lived in an institution for people with mental disorders, and had allegedly never spoken a single word during her life. However, shortly before her death, she unexpectedly sang a church hymn clearly and coherently. Her Caregivers and medical staff at the asylum were witnesses to this miracle.

There are multiple well-documented cases like this. For example, The case involving a 91-year-old woman with advanced Alzheimer's disease who experienced terminal lucidity is documented in the research conducted by Dr. Alexander Batthyány. There are also multiple cases in Dr Peter Fenwick's research where people with severe psychiatric and neurological disorders have come back with mental clarity for a short time before death and conversed with their family members.

There are some explanations for terminal lucidity. I will explain the criticisms to a couple of them. One is the electrical surge of gamma activity that occurs after the heart stops beating. This electrical activity lasts for a short time. This is not a reasonable explanation for veridical OBE NDEs, the reasons I have already stated above. However, when it comes to terminal lucidity, a case could be made that this activity is at least related to the experience. However, it should be noted that "this electrical abnormality could just be cell membrane losing activity because of lack of oxygen. Neuromodulation was also proposed as a theory to explain Terminal lucidity. However, it is an untested hypothesis. Another theory was by Johannes Friedreich. He suggested that the causes of Parkinson's disease and Alzheimer's disease reversed at a time just before death, allowing for mental clarity. He stated that this could have happened due to fever. However, none of the terminal lucidity cases include a high fever.

Conclusion

As I pointed out in the "What, then, is the correct solution to the mind-body problem?" section, my sole purpose in writing this paper was to give what I believe to be empirical evidence for the non-physical. The first part of this paper was to provide a clear introduction to the mind-body problem and the proposed solution to both sides, but my primary purpose was to prove that materialism was not valid. I would also like to clarify that the other two perspectives that I mentioned, dualism (in the sense that matter and mind are two of the fundamental substances) and idealism, are probably not the entire story either, but an introduction to a set of ideas that could hypothetically fit in our scientific model given that we acknowledge NDEs and terminal lucidity as empirical evidence for the existence of the non-physical.

“It’s like trying to draw an odour with a crayon.” In this paper, I consciously decided not to focus much on the “more real than real” aspect of NDEs that people who have gone through NDEs talk about even when there is no electrical activity going on in their brains to generate the lucidity of their experiences that they talk about. I chose not to talk about “colours, sounds, and music that could not be described with words” and “cannot be replicated on Earth” claims. I would like to address why.

While these claims happen often in NDEs and are statistically reported to be a majority of people, they are anecdotal and unverifiable. I firmly believe that trying to make someone understand an experience without them experiencing the experience themself is impossible through words. I believe this for something as simple as happiness, sadness, anger, etc. For example, is it possible to make someone who has never experienced anger (hypothetically) understand it just through the use of words? Try as we will, it is not possible to describe anger perfectly through words. What use is it, then, trying to explain experiences that are “more real than real”?

The second and most important reason is that claims like that are purely anecdotal and hold no scientific validity. The reason I specifically chose veridical OBE REDs is because the NDEr has details that happened during the surgery that he could not have known unless he saw it or heard it himself.
The three NDE cases that I have stated are handpicked cases that I see as almost flawless in demonstrating this aspect of veridical REDs. This knowledge proves the initial purpose of this paper: that something non-physical exists, at least for a short amount of time.

As for Terminal Lucidity, Although 94% of the paradoxical lucidity patients end up dying less than a week later, the fact that there are even 6% of cases where the patients end up living longer than a week seems to point to the fact that it may very well just be something generated by the brain. Whenever I introduce the concept of terminal lucidity to people, they either say that they will find an explanation for it and never contact me back or wholeheartedly accept that it is an intended phenomenon by God. As I did with NDEs, I will do here again. I believe that we should stand in the middle of these two extremes. Skeptical about the fact that such an experience can indeed be introduced by nature, but also doubtful of the explanation of “God did it to give people happy endings.” Why, then, doesn’t every Alzheimer’s disease, Parkinson’s disease, or schizophrenic patient have paradoxical lucidity or even terminal lucidity? Why did God choose this specific minority to have this return of mental clarity? There is no well-documented study explicitly investigating the correlation between religious beliefs and the occurrence of terminal or paradoxical lucidity in psychiatric patients. However, it is well-documented and recognised that NDEs are cross-cultural. That is to say, atheists have NDEs, too, and they aren’t hellish NDEs either (Not to say that atheists have never had hellish NDEs. Studies on NDEs, such as

those by Bruce Greyson and Kenneth Ring, have documented both positive and negative experiences across a wide range of individuals, regardless of their religious beliefs or atheism.

Relating back to Terminal lucidity, there is no evidence at all to suggest that God specifically gives the religious ones NDEs and terminal lucidity. In fact, there is strong evidence against it. Returning to the "Terminal lucidity is caused by nature" explanation, there is no medical consensus on what causes terminal lucidity, and the criticisms for every explanation are strong. Acknowledging the fact that there is an argument that could be made from the psychological and evolutionary perspective, i.e., such a mechanism could be seen as beneficial for both the individual and their social group. For the individual, a peaceful death could reduce suffering. For the social group, witnessing a loved one die peacefully might mitigate grief and provide a sense of closure. However, until and unless we explain how the brain could defeat diseases like Alzheimer's and Parkinson's by itself, and coincidentally usually at the end of life, we will not be able to satisfactorily dismiss Terminal lucidity as evidence for the non-physical, either.

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SPECIFICALLY NDEs

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(limited knowledge of some of the scholarly articles in this due to my limited understanding of med. Science. Most of the things I state are direct quotes/ paraphrases of what the doctors have said and their reasonings that make sense to me.)

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Culture and value - Ludwig Wittgenstein

Light and Death: One Doctor's Fascinating Account of Near-Death Experiences" - Michael Sabom