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The Cause of the 2008 Housing Market Crash and the Aftermath By Kwanhee Lee

Abstraction

The 2008 Housing Market Crisis, considered as one of the most catastrophic economic crises in U.S history, truly left some irreversible dents to the U.S economy. The Mortgage Backed Securities, which started as a simple business idea, added with greed and ignorance of various financial institutions, was enough to topple one of the most prosperous economies during the time. The efforts to remedy the aftermath weren't any more successful. Printing billions of dollars was the final conclusion that was reached. In the end, the devastation that was fundamentally caused by greed and ignorance was resolved by a solution that was fundamentally based on shortsighted thinking. All this contributes to an unstable and uncertain economy of today.

Background

In 2008, the booming American economy backed by the U.S housing market collapsed nationwide. Except for a handful of people, no one saw it coming. The housing market was so stable that most people dared to think that it was the core problem. In the end, the housing market crashed, taking down Bear Stearns and Merrill Lynch, bankrupting Lehman Brothers, and almost collapsing the entire U.S economy. How did something so stable devastate the entire U.S economy? It initially started with Lewis Ranieri's Mortgage Backed Securities (MBS). Where once a single mortgage had low risk and low yield, the MBS, which grouped thousands of mortgages together, still had low risk but a much higher yield. After Lewis Ranieri founded the MBS, bankers started making absurd amounts of money. This was the beginning of an era of prosperity of Wall Street. One problem was that it didn't last.

The Beginning

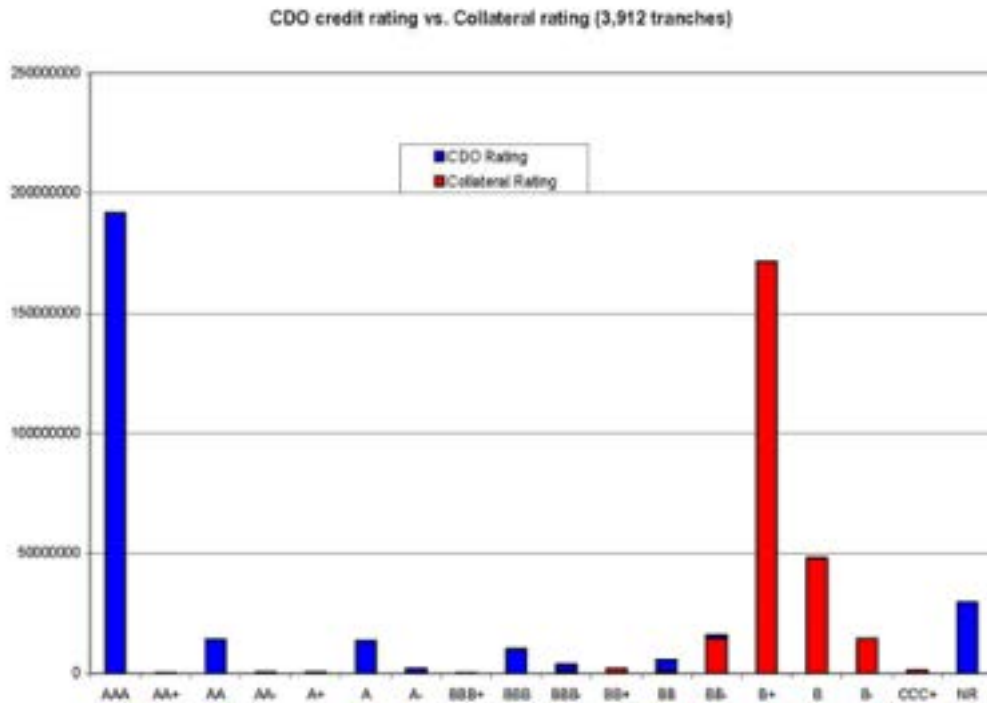
During the early 2000s, the Fed kept the interest rate relatively low. This allowed for cheap borrowing of money. The easy access to credit fueled the economy and led to an economic boom. The economy was initially stable because the growth of the economy led to rise in income and rise in asset values. This made people creditworthy, leading to more borrowing. Somewhere along the line, the Fed increased the interest rate because prices were rising too rapidly. The increase of interest rate meant that money was not so cheap anymore. The debt burden of individuals started to rise as well. This led people to be more reluctant to borrow because of higher interest rates and more reluctant to spend in order to pay their debts. This is where the rising trend reversed itself. As borrowing decreased, spending decreased. As spending decreased, incomes decreased. As incomes decreased along with asset values, creditworthiness decreased. As creditworthiness decreased, lending decreased. As lending decreased, spending decreased even more and so on. The rising debt and rapid increase in asset values pointed to the conclusion that a peak had been reached and deleveraging was bound to occur. There are reasons however, for why the deleveraging in 2008 was so devastating. In broad terms, greediness, sloppiness,

carelessness, and wrong ideas all contributed to the downfall of MBS, which led to the downfall of the economy. But in detail, there were clear indicators that the housing market was not going to last. Those indicators were an increase in rating fraud, increase in subprime mortgage lending, and exposure of banks to a housing bubble.

The Middle

1. Rating Fraud

The rating agency rates the mortgages bonds by AAA, AA, A, BBB, BB, and B. A rated bonds are relatively safer and generally lower on return. B rated bonds on the other hand are relatively riskier and generally higher on return. The job of the rating agency is to rate the mortgages accordingly, so that investors know what they are investing in. At least that was the purpose of the rating agencies until Collateralized Debt Obligation (CDO). A CDO is a package of all the unsold mortgages. It mostly consists of risky mortgages such as BBs and Bs. When the package becomes large enough, the unsold, risky subprime loans [1] get a new rating. This is where the problem occurs. No one knew what was actually in the underlying bonds. Even the rating agencies, they didn't know exactly how much of Bs, BBs, or BBBs were in these bonds, but most of the time it was rated over 90% AAA because that's what the banks wanted. The CDOs that were labeled safe were actually composed of underlying subprime loans like Bs, BBs, and BBBs that could fail any time.



Source 1: This shows that while the CDOs were mostly rated AAA, the underlying loans were mostly Bs and BBs [2].

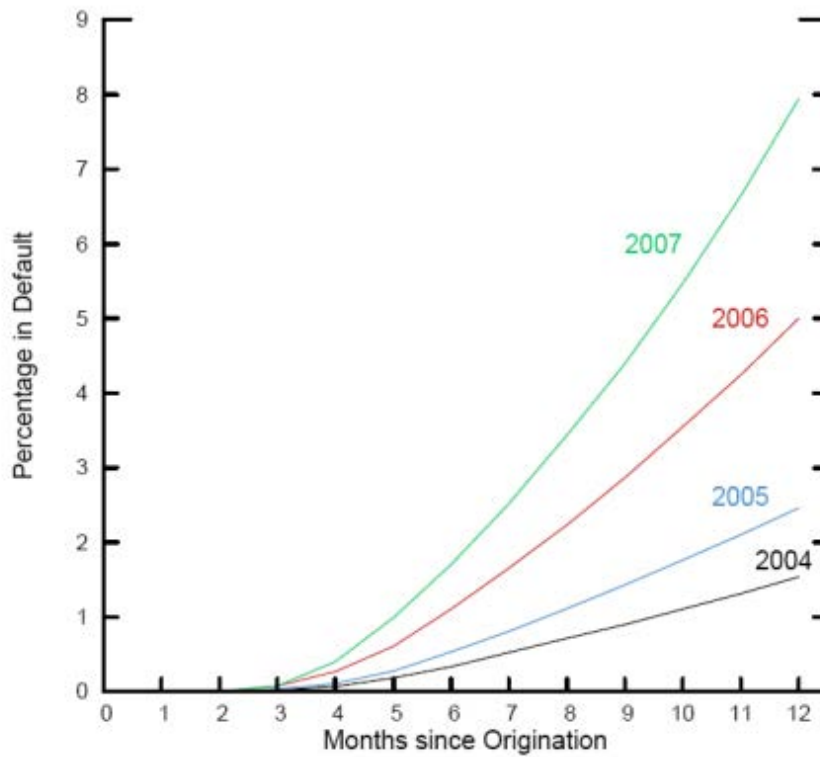
2. Subprime Mortgage Lending

A subprime mortgage lending is a form of mortgage lending to people with poor credit history. These lendings are riskier because payment is not guaranteed by the previous history of credit. Also subprime mortgages charge more interest rate than fixed rate mortgages, which makes it more profitable for banks. One of the main reasons why subprime lending rose was because of the low interest rate set by the Fed. Since the Fed has kept the interest rates low, fixed rate mortgages weren't returning high enough yields. In search of higher yields, lenders turned to subprime mortgages, which were more profitable. Another reason for the rise in subprime loans is because of the rise in demand for subprime adjustable rate mortgages (ARMs). These subprime ARMs are also known as teaser rates. They start off with a low monthly interest rate, but after about a year, they start to increase. Adjustable rate mortgages were appealing to immigrants and people with low FICO scores [3] because they initially paid less than a fixed rate mortgage. It can be seen in Source 4 that a few years before the 2008 market crash, the balance of more than 80% of the ARMs were already larger than they were at origination, and in 2007, more than 90% of the ARMs were larger than they were at origination. People with low incomes and poor credit history now had to pay more monthly. This led to delinquencies of payment shown in Source 2, which ultimately led to rise in default rates shown in Source 3.



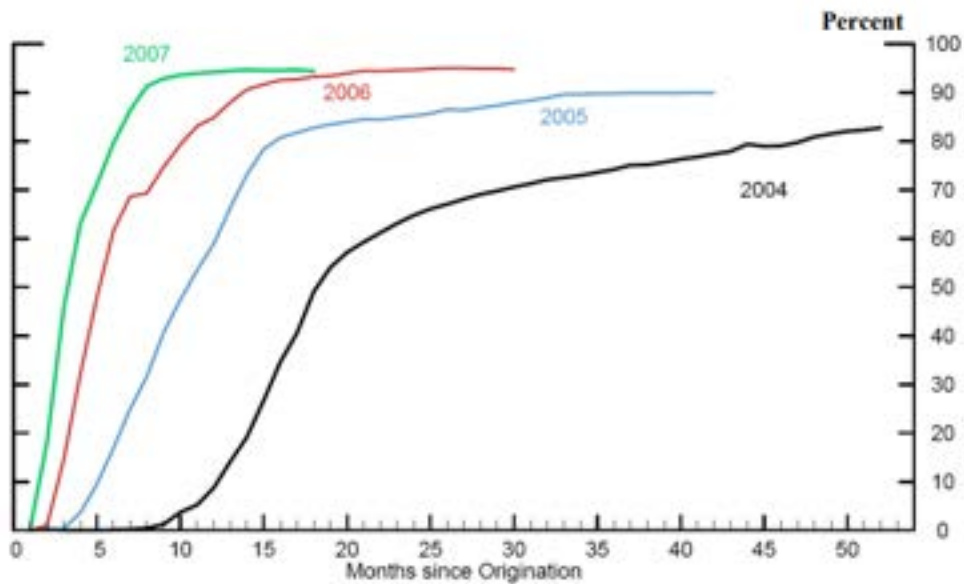
Source 2: This shows that Delinquency rates of mortgages rapidly rose from less than 2.5% in 2006 to about 12% in 2010 [4].

Early Payment Defaults on Subprime Loans



Source 3: This shows that mortgage payment default has continued to rise since 2004 and reached 8% in 2007 [5].

Option Adjustable-Rate Mortgages with Balances Larger than at Origination



Source 4: This shows that most ARMs balances become larger than original over time. In 2007, less than a year before the crash, more than 90% of ARMs balance became larger than original in less than 10 months [5].

3. Exposure of the Banks

The banks were the major dealers of subprime loans, and during the early 2000s, the banks started loaning more subprime ARMs. As mentioned above, subprime ARMs were favorable to the banks during a period of low interest rate. As a result, in 2006, the top ten investment banks sold over \$1.5 trillion in mortgage backed securities grouped with subprime loans and other assets. The banks also started lending credit to subprime lenders and sometimes purchased them [6]. This is how the investment banks became closely associated with the subprime sector of the housing market. However, when a good number of people defaulted, some banks that were highly exposed to this risky investment started losing money. This led to a fright among investors and hedge funds. They hastily withdrew their investment, depleting the bank's liquidity. This is how Bear Stearns failed. After the failure of Bear Stearns, investors and ordinary people went into panic. Like a domino effect, investors withdrew money from other banks and individuals withdrew money from their accounts. At the same time, these banks were taking losses from the defaulting in the subprime sector. These banks were going down a downward spiral with defaults and liquidity issues. If the rise in rating frauds and subprime lending were just the previews, this chain reaction that devastated the investment banks was the grand finale.

The End

People believed that the upward trend of the US economy would last forever. This fallacy was the reason asset prices inflated and created an asset bubble. Although asset inflation sounds scary, to the public, this was known by a different term: economic boom. This led people to rejoice in the inflating housing market and cheer as the bubble grew larger. In the midst of fraud, carelessness, and greed, big banks and companies continued to invest in risky mortgages because they thought the market would not fall.

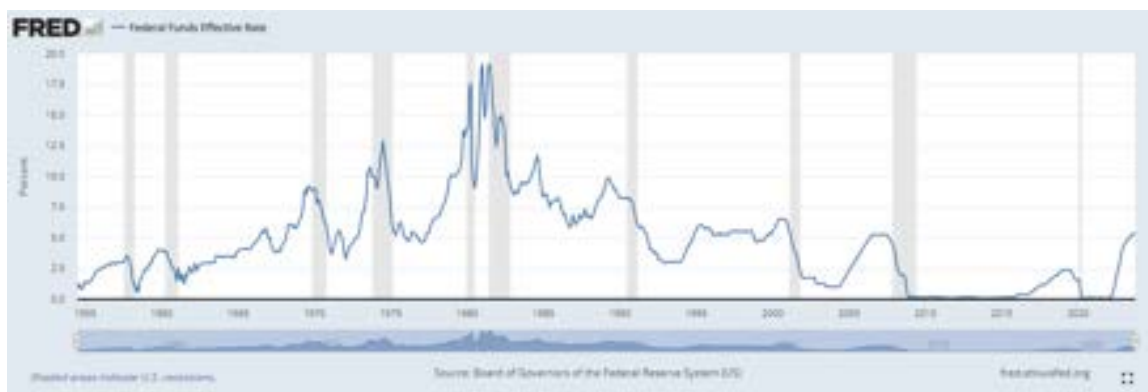
The Aftermath

After the market crashed, GDP fell 4.3%, unemployment rate rose up to 10%, millions lost homes, poverty rate rose to 15%, a quarter of households lost 75% of their net worth, and more than half lost 25% of their net worth [7]. The economy was in an extremely desperate state. Unemployment rates were rising and economic growth was stagnant. Bear Stearns was sold to JPMorgan Chase, Merrill Lynch was sold to Bank of America, and Lehman Brothers filed for bankruptcy. People lost trust in the big banks and they drew their money. While the U.S. economy was deleveraging rapidly, Henry Paulson, the Secretary of Treasury, Ben Bernanke, the Federal Reserve chairman, and Timothy Geithner, the New York Fed president, came up with a

solution to reverse the downturn. The desperate attempts to revive the economy were known as zero interest rate policy (ZIRP), quantitative easing (QE), and bank bailouts.

1. Zero Interest Rate Policy (ZIRP)

The Federal Reserve, after the crash, set the interest rate to zero in order to remobilize borrowing and spending, and in order to boost the economy. However, this was rather ineffective because the majority of people didn't have enough money. The reason was that people before the crash mostly owned assets. Assets have monetary value, but they are different from cash. Most of what people thought was their cash before the 2008 crash was actually assets, but until liquidated, assets always have a potential to lose value. So, in other words, even though the Fed made the atmosphere favorable for borrowing and spending, the majority of people didn't actually have the money to spend or reliable income to borrow. Underneath the apparent inefficiency, however, the ZIRP had an effect on something. But it was not a positive effect. Thomas Hoenig, the Kansas city Fed president, described this as the allocative effect. Imagine a scenario where the interest rate is higher such as 5% or 6%. In this case, the banks can store their money in safe investments such as the U.S Treasury Bond, where the return is favorable due to higher interest rate. However, when the interest rate is 0 or near 0, the yield is basically nothing or close to nothing. This prompts the banks to find investments, sometimes risky investments, with higher yield than 0. This leads to economic growth but also asset inflation.



Source 5: This graph shows the interest rate set by the Federal Reserve from 1955. From 2009, the interest rate was near 0 for more than 7 years [8].

The long duration of ZIRP shown in Source 5 made it worse. For more than 7 years, the interest rate was kept near 0. This ultimately normalized the investment in riskier markets because the safer investments were not profitable. Big banks and companies invested in assets for higher yield, which drove up the asset price, leading to yet another asset inflation.

2. Quantitative Easing (QE)

Another method used by the Fed was called quantitative easing (QE). The principle of QE is to print billions of dollars. The Federal Reserve, with the newly created money, will then buy treasury bonds from primary dealers, usually big banks such as JP Morgan Chase. Finally, those primary dealers will release the money into the economy by buying assets. The most fundamental issue with printing large amounts of money is the devaluation of currency. The more dollars in circulation, the less those dollars were actually worth. In addition, the banks had no incentive to make safe investments with the newly created money due to near 0 interest rate. This led to riskier investment and stroked even more asset inflation.



Source 6: The graph shows the timeline of the Fed's balance sheet from 2003 to 2016 [9].

The first QE was in November of 2008. In Source 6, before around 2009, the Fed's balance sheet was relatively stable. It was rising, but at a slow and steady rate, and not exceeding 1 million. After the first QE, the Fed's balance sheet more than doubled, and since then, it has continued to rise. After the first, 3 more came. 2 more before 2015. This action of pumping money into the economy eventually led to top 10 investment banks owning more than 20 trillion dollars in assets.

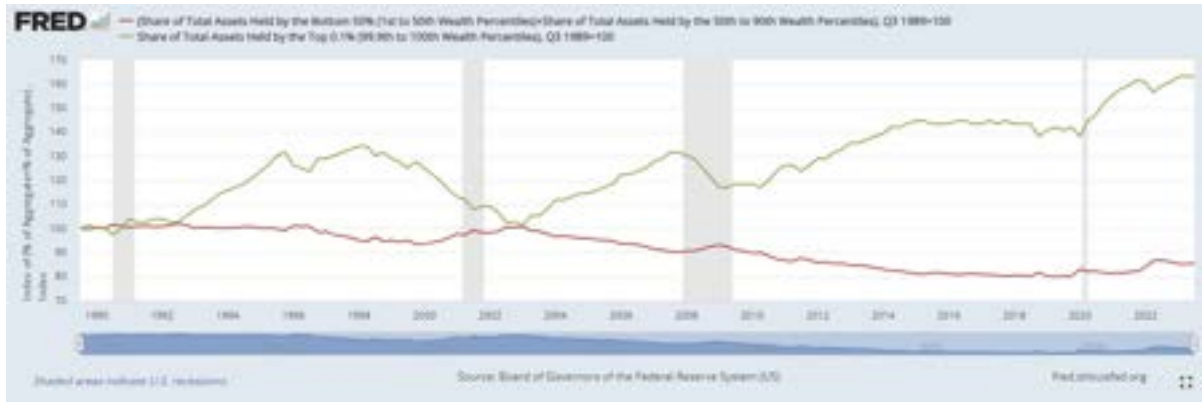
3. Bank Bailout

The last method was the bailout. As mentioned above, in addition to Lehman Brothers, which collapsed completely, 2 other investment banks have failed as a result of the financial crisis. To Secretary Paulson, restoring the trust of the public in the banks was crucial. He believed that without drastic action, all the financial institutions would fall one by one. His drastic action was the massive bailout of the investment banks. The total sum of the bailout money was more than \$10 trillion. The banks that were given a portion of that sum were classified as "Too Big to Fail." Too big to fail, not because they had so much money that they could solve any problem, but because they had so much money, the government could afford to let them fail. In other words, they can't fail

because the government won't let them fail. They will do drastic actions necessary to keep them alive. This action in 2009 was the \$10 trillion bailout that made the banks even bigger. Although they supposedly can't fail, if they do, this lifeline that Secretary Paulson has thrown at the banks have only made the consequence of potential failure much greater.

Conclusion

The Department of Treasury (DOT) and the Federal Reserve were in a dilemma. On one hand, they could use extreme forms of intervention and unconventional monetary policies in order to stabilize the economy and postpone its impending doom. By doing so, the DOT and the Fed would be putting the needs of the people first. The issue with this is that, in the long term, the future of the US economy would become uncertain. On the other hand, they could use less extreme forms of interventions in order to secure the future economy. By doing so, the DOT and the Fed would be extending the duration of the hardship of the people. Both options would lead to pros and cons, but the decision was the first option, which was to help the people in need at the risk of an uncertain future. As noble as this sounds, however, there was one problem: the interventions and monetary policies helped the big banks far more than they helped the people who were really in need. Billions of dollars printed for QE went to the big banks which were the primary dealers. Billions more went to other investment banks for bailout. All this was essentially more money for the banks to buy more assets. When banks bought assets, the economy stabilized and investors regained trust. However, this was mere insignificance to the people on the streets, to people living in tents, and to people with no food. While Wall Street was getting all the help it could get, the people that were suffering were left mostly on their own. Source 7 clearly captures this situation. It is true that during 2008, the top 0.1% experienced some setbacks and the bottom 50% saw slight increase in asset ownership. Almost immediately after 2008, however, the amount of assets held by the top 0.1% soared while the amount of assets held by the bottom 50% declined. The timing of this rise and fall miraculously corresponds to the date of first QE. In other words, not only did the DOT and the Fed essentially neglect about half of the U.S population, they have put the future of the U.S economy at stake for 0.1% of the U.S population. All this short sightedness and greed has led up to an insecure and fragile economy, similar to the one that caused the market crash of 2008 in the first place.



Source 7: This graph shows the amount of assets held by the top 0.1% and the amount of assets held by the bottom 50% [10].

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The Ethical Supremacy of Deontology Over Consequentialism By Omar Obeidat

Introduction

The divide between deontology and consequentialism has been a prominent issue in philosophy for thousands of years. The debate over which ethical theory prevails holds outstanding implications for the world as a whole and how it has come to be. Given that morality is at the forefront of decision-making, and that such decision-making determines humanity's sole contribution to the universe, the ideology that most accurately reflects it ought to prevail. This paper will argue that deontology is a more accurate ethical theory than consequentialism.

Objective Outcomes

The first premise is that dependency on outcomes results in an objective reality. Consequentialism supposes that human action is directly correlated to the state of mind without attention to alternate causes. It disregards the numerous and indiscernible variables that influence the human mind. By holding all the value of an action in its outcome, the theory assumes that such outcomes are objective. Otherwise, its subjective nature would collapse under a deontological approach concerned with the individual's duty.

However, outcomes are a mere representation of the mind and can not be uniform across all of humanity. Deontology instead offers the unique capacity of being fluid, with a vast array of potential measures for the individual to pursue. More importantly, the traditional application of consequentialism as a means to promote utilitarianism for the sake of well-being is still more suitably upheld by deontology. Consequentialism condemns the individual's happiness, arguably their ultimate goal, to the precise action they carry out. In suboptimal conditions there is thus a lack of potential happiness or morality as a whole. This is inherently self-contradicting, as consequentialism exists to promote morality in the first place yet fails to endorse it at the sign of dire circumstances.

To illustrate this point, consider the following hypothetical example: Bob the journalist comes across a document that exposes government fraud. By publishing the document, Bob faces legal consequences and the threat of unemployment. If he decides to keep the information confidential, Bob allows corruption to persist. Both courses of action are suboptimal and fail to promote well-being. Even the principle of mitigating detriments is obscure and non-absolute in an uncertain future. Bob is condemned to two negative outcomes, and he can not even tell which reduces harm the best. Under a consequentialist philosophy, Bob's own happiness and life's worth is correlated to an inevitably poor decision. Some might argue that consequentialism is relative to the situation, and so if Bob makes the best out of a mediocre position, then that is a righteous act. However, if the universal standard succumbs to case-by-case fluctuations, there can be no objective reality. Specifically in a world subject to vastly different perceptions and beliefs, there can be no single law of morality. The consequentialist theory fails the universalizability measure, and should it ever be applicable in a specific situation, it would collapse under the framework of deontology. Such an ethical theory allows different interpretations of morality to be applied

depending on the circumstance itself. It is only when individuals can appreciate the constant failure of philosophical ideologies to be relevant in every possible scenario that they realize the urgency for a theory to unify every diverse and valuable impression of morality. Simply put, there can be no objective reality, and that is consequentialism's fundamental flaw.

Moreover, the state of mind is a morally superior metric to any physical event, meaning it is rational to only focus on the intrinsic morality of an action. One might argue that it is the state of mind which defines the physical event given that the world is what individuals make it to be, and yet this only places further emphasis on the inherently moral weight of an action. In the event that consequentialism concedes the solipsist argument, it can not place such weight on objective impacts when it is the very mind that creates them. Deontology must instead prevail since any subjective perception of morality becomes the duty of the given agent. Even if every subjective reality argument is rejected and objectivity succeeds, it is still irrational to determine the morality of an action by its consequence. The nature of the universe may be probabilistic, in which case outcomes are random and there can be no association between an action and its specific outcome. It would otherwise follow a deterministic model so that the consequence is dictated prior to the action, such that the action has no impact at all. It would thus be trivial to question the morality of an action since it can not be altered.

In summary, consequentialism indicates a direct association between the individual's action and the outcome while neglecting alternate causes. This enforces an objective perception of reality as the values of morality and well-being are rigid, although outcomes vary by the conception of the human mind. Meanwhile, the binding tie between action and consequence is ineffective under suboptimal circumstances. In such cases, no action promotes the endmost good and any attempt to maximize prosperity collapses under deontology. Since the state of mind is everything, it is imperative that an ethical theory adapts to the subjective nature of reality. The paramount fallacy in consequentialism is that it assumes an objective reality.

Subjective Reality

The second premise is that there is no such thing as objective reality. The world is only what any given individual makes it to be, and solipsism is unfalsifiable. There is nothing anyone can point to that is not a conception of their own mind. Belief is therefore no different than truth since they are both to exist in the mind. This quality of existence is its own degree of truth because the given thought is always in accordance with some faction of the mind. Even the imaginary pertains to the fantasy sector of the mind. Since there is no reason to assert higher moral value to any one category, it is logical to assume them all equally valid. When it is irrational to prefer hard reality over any other faction of the mind, there can be no single objective reality. Truth varies so long as people's beliefs differ.

And yet to claim that there is no such thing as truth is in and of itself a truth. The people are bound by their own frail human reasoning. They must resort to assuming something or else succumb to an infinite regression. Each and every truth can be questioned so that the world can do nothing but stare into a void of nihilism. Thus, the human being must assume truth despite it

causing its own fallacies because it is the single notion that can never be critiqued. Any thought conjured or conception realized is its own truth such that truth is only to exist in the mind. Every thought expresses, or even is, the world around it. Even contradictions and rudimentary dilemmas in philosophy only assert truths of their own.

It may even be argued that truths are the only thing in the universe. Since any subject, in the physical or mental world, is perceived by the human mind, it can be proclaimed a thought. Additionally, nothing can surpass the individual's mind, for if they conceived something that could it would in fact be within their own mind. The human mind is therefore everything while all the thoughts within it are truths. Thus, everything is a truth. It is such that people assume truth.

The fallacies in truth are their own truths, and the circle of reasoning never falters. The alternative to assuming truth would be to reject the human search for meaning. The infinite regression due to the absence of postulations would hence be justified, though it is counterproductive to any human goal. One might reject any human goal or meaning in life and embrace the infinite regression but that is the drastic opposite of consequentialism. The consequentialist ideology can not reject life's search for meaning because it revolves around the presumption that human beings strive for happiness and well-being. Likewise, the reader would be required to neglect such a pursuit in the first place since by grasping it now they offer the pursuit of happiness the gift of truth. Even if the reader was unaware of the pursuit, they would never perceive its rejection since by validating a rejection, the subject being rejected is naturally proposed.

To elucidate, examine Bob once again. If Bob were unaware of the government fraud, he could not forgo the incident occurring. Even if it was utterly beyond Bob's comprehension, by consciously revoking the possibility of government fraud he accepts the notion that it might have occurred. Thus, rejecting the pursuit for meaning only validates it. It is a fundamental assumption along with life itself. No conception can be denied for they all exist within the human mind, and were one rejected it would indicate that it is beyond the human mind. And yet, the human mind is everything. Nothing can be denied before it crosses the individual's mind. And once it crosses the individual's mind, it can not be denied.

One might infer that every proposition in reality is true, and perhaps they are. Should they contradict, that is a truth in and of itself. If everything is true, then when all is said and done, the fact that deontology surpasses consequentialism is also true. If every contradiction is true then there can be no real contradictions. And yet, individuals may resort to the notion of objective truth as an assumption given the procedure of human thinking and the inexplicable intuition within the people to assume such. Though it just as quickly falls apart in a cyclical agenda of the mind's own perception. Whatever is said and done, it always exists within the subjective conceptualization of the given individual's mind. It is assumed before all else that there is only what the individual can see, and that is the highest standard of them all.

To conclude, solipsism prevails above all else such that any given thought is in some sense true. Yet when objective reality is also true, a contradiction arises and sparks an infinite

regression. It is only rational to assume truth and the pursuit of meaning in order to avoid the nihilistic regress. Such trivialism collapses into the subjective content of the human mind. The notion that everything appears to be objective is the very nature of one's inherent subjectivity. To claim that something is true, to conjure any thought at all, is a dynamic perception of the mind. Ultimately, only a subjective reality can truly be assumed.

Intrinsic Morality

The third premise is that deontology exists under subjectivity but can also offer intrinsic moral values. Such values are the bare foundation for what an individual ought to do, since there must be a truth that is most foundational. Without a bedrock for functional reality, the infinite regression prevails and the world is meaningless. The regression can not exist as it would remove the grounds for absolute truths. Even the observation of an infinite regression would succumb to the infinite regression. Therefore, a foundation must exist so that truth may emerge. The solution is ensuring that the groundwork is absolutely and unequivocally true, a prerequisite to questioning anything else for it is what has defined truth. Some might argue that asserting a foundation to construct all truth is in and of itself a truth; that one must utilize truth to create a framework of truth, but such is the infinite regression. It is such that the people must assume.

Since solipsism and a fundamental assumption prevail, the assumption must manifest, or even determine, the nature of the human being. One might even claim that human perception and the real world are interchangeable, since reality is a mere expression of the mind. As a result, the assumption must make a statement on intrinsic morality as that is ultimately what guides the human mind, and perhaps all that exists. Some may argue that the pursuit of happiness is foremost, as it is the human being's greatest incentive. Yet it is morality which the individual is seeking since only a moral life can create happiness. Should it be the principal motivator, happiness is still a mere byproduct of leading a moral life.

If one argued that morality can not simply be assumed, then it would no longer be an assumption. One is condemned to blindly accepting an assertion that can never be questioned, so long as it is an assumption. There can be no reason why any given assumption must be preferred over another, for the nature of human thought is the highest imperative. Consequently, this paper assumes morality and any critique of it is missing the point. The assumption is most integral to reality such that any reason to prefer it is sourced from the assumption itself. Morality can therefore not be compared, since any competitor relies on the very premise of morality in this subjective reality.

Since morality must be accepted as the fundamental assertion, it is crucial that deontology offers such values. Even if one should assume happiness instead, there is no physical consequence that determines happiness but the reaction of the mind. As both happiness and morality are perceived in a subjective reality, it may even be argued that they are identical to the human mind. Since the human mind comprises the entire universe, nothing matters but thoughts, while happiness is merely another thought. It is critical that one thus examines the basis of all thoughts, although one can only conjure more thoughts. A circle of reasoning prevails so that a

meta-analysis can never be conducted. That is when it is imperative that one asks what they are here for in the first place. That would transcend happiness for there is a stark realization that there is more to the world than such an artificial pursuit of pleasure. That, in fact, is morality.

In fine, the only value remaining is morality given a subjective reality. It must be assumed above all else, or else one succumbs to the infinite regression. Even then, happiness is no longer a cause and the individual turns to question the meaning of life in the first place. Such conditions transcend a desire for pleasure so that morality can be the only guiding principle. Since it is the most fundamental assumption there is, morality can not be compared to any other value or it would not be assumed. Thus, happiness is left in a double bind—if one rejects the infinite regression, happiness is a byproduct of leading a moral life; if one accepts, happiness no longer has any value and the only plausible outcome is a pursuit for bare and utter morality. Deontology therefore surpasses consequentialism in its ability to offer inherent morality as the bare foundation of reality, as opposed to highlighting the allegedly objective pleasure produced by a given action. Since it functions under a blatantly subjective world, and since happiness can never truly prevail as the ultimate goal, deontology is a superior ethical theory to consequentialism.

Conclusion

In summary, the first premise is that consequentialism hinges on objective outcomes. Not only does the method deteriorate under poor conditions, but it exacerbates an objective reality that neglects the intricately dynamic nature of the human mind. Secondly, there is no such thing as the alleged objective reality since the perception of the mind is all that exists. Solipsism endures because any claim one could ever make is a notion they have conceived within their own mind. Even if all arguments are reduced to comprehensive truth, and contradictions appear valid, the occurrence is in and of itself a product of one's mind. Every argument against subjective reality belongs to an individual's personal discernment. Finally, morality prevails in such a subjective reality for happiness is a mere byproduct of leading a moral life. Furthermore, the grandest and most insightful of conceptions would examine the infinite regression. If every assumption is questioned and none are left, so that there is nothing one can do but stare into a nihilistic void, then the only remaining principle, after happiness decays, is what is truly, intrinsically moral. Thus, deontology's groundwork of innate morality surpasses consequentialism's reliance on happiness.

Because dependence on outcomes enforces an objective reality, there is no such thing as an objective reality, and only deontology can offer fundamental moral values that far outweigh objective happiness, deontology is a more accurate ethical theory than consequentialism.

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A History of OB GYN: Society's Stigmatization of Women's Sexual and Reproductive Health By Suhani Sharma

Abstract:

This paper discusses the history of OB-GYN and society's stigmatization of OB-GYN, which results in a lack of knowledge about women's sexual and reproductive health. The history discusses the creation of OB-GYN, why it was created, and the lengths it took to get to this point in science. The paper goes through many periods and discusses obstetrical and gynecological advancements during those centuries. The main focus of the paper is to acknowledge ways that the discussion of women's reproductive health has not been taught actively which leads to repercussions for women. The taboos around periods, sex, and reproductive organs cause a gap in knowledge for both women and men and create the belief that sexual health is "wrong" or "shouldn't be discussed". The paper also attempts to make recommendations about how to fix society's lack of knowledge about OB-GYN and women's health.

Key words: Women, Obstetrics, Gynecology, Sexual Health

Introduction and History of OB-GYN:

The study of gynecology and obstetrics has existed for centuries. The earliest known text that details advancements of OB-GYN is the Kahun Gynecological Papyrus, written in the twelfth dynasty of 1800 BC.¹ This text details information on childbirth, pregnancy, and gynecological diseases.¹ It's possible that OB-GYN studies could have existed before this, but currently, this is the oldest known text that discusses women's health.¹ Since then, OB-GYN has continued to be studied and researched. During this period, the main focus was on the study of obstetrics, childbirth, and midwifery. For most ancient civilizations, obstetrics was studied in some order to allow for more successful childbirth. This purpose continued up to and throughout the Renaissance.

During the Renaissance, midwifery was very important. Local midwives continued to help with childbirth. Due to the invention of the printing press, there were pamphlets and manuals made on how to properly be a midwife and how to take care of newborns.² Even though women served as midwives, the main producers of these templates were often men who had little to no firsthand experience with midwifery.² These pamphlets were mostly printed in Latin which resulted in very little of the population being able to read them.² The most important obstetric book published at this time was *Der Schwangeren Frauen und Hebammen Rosengarten*. The Rosengarten was published in 1513 by Eucharius Rosslin. It is one of the only books written to directly address midwives, so it holds an extremely important place in the history of midwifery.³ The Rosengarten proceeded to be translated into many different languages including Latin, Czech, Danish, and French.³ Today, concepts in Rosslin's book continue to be used and applied throughout all of midwifery and medical training.

Soon after the Renaissance came the Enlightenment. The Enlightenment period was a time when the idea of "obstetrics" and "midwifery" changed forever. Before the Enlightenment,

midwifery was not considered a science but, more so, a sacred intimate world between the mother and the midwife.⁴ Men were not even allowed to enter the birthing rooms.⁴ Midwifery was not considered something that was taught but instead, was learned through years of experience.⁴ This all changed during the Enlightenment and Scientific Revolution. The Enlightenment was a period when thinkers focused on reason and applied it to all realms of life. This thinking resulted in OB-GYN being treated as a part of science and required midwives to formally receive an education. One main forefront of this was William Smellie.⁵ William Smellie had studied surgery and was interested in midwifery.⁵ At his apothecary shop, he would treat poor women for free which allowed him to study obstetrics.⁵ He took on students who followed his example,⁵ further spreading the study of midwifery. Smellie also created the first pair of obstetrical forceps,⁵ truly cementing midwifery as a part of science and surgery. More people like Smellie also joined, resulting in universities teaching midwifery. This is an extreme change from just a century ago when men had nothing to do with midwives. Soon, male midwives were created and they began to change traditional midwifery. The creation of men midwives was huge and was often frowned upon by less secular societies.⁵⁻⁶ The men who practiced obstetrics were often mocked, as seen in Isaac Cruikshank's pamphlet that depicted a half-man, half-woman midwife.⁶ Regardless of these opinions, men continued to study midwifery and OB-GYN. By the end of the 18th century, a considerable number of men were midwives, although the main proportion of midwives continued to be women.

In the 19th century, arguably the most important person in the history of obstetrics and gynecology was born. That is the father of gynecology: J. Marion Sims (1813-1883).⁷ Sims was a surgeon who successfully treated vesicovaginal fistula,⁷ which is when there is an opening between the bladder and vagina.⁸ This is an extremely difficult complication in OB-GYN. Along with treating this, he also successfully completed the first gallbladder surgery.⁷ Sims also created tools that allowed for better vaginal examinations that helped further OB-GYN; he created a vaginal examination position and the speculum which is currently used at OB-GYN clinics today.⁹ Although Sims has done important work to help further gynecology, the work he did was tested on Black enslaved women.⁷ He would operate on slaves without consent and would treat them without any anesthesia due to his belief that Black women did not feel the type of pain or the extent of pain that white women feel.⁷ J. Marion Sims' contributions have been widely disputed and continue to be argued for and against today. However, one undeniable thing is the effect Sims' work has played in shaping modern-day obstetrics and gynecology

Continuing through this time, the American Gynecological Society was finally founded in 1876. During the 20th century, the role of midwives advanced and became a regulated system. There began to be an increase in both home deliveries and hospital deliveries.¹⁰ There also began to be a focus on prenatal and postnatal care during the 1900s, along with a new age of technology that helped regulate women's health better.¹⁰ Many different inventions were created, including the ultrasound and amniocentesis, that helped further OB-GYN advancements.¹¹ Today, OB-GYN stands as an important part of any woman's life and continues to explain and protect women's sexual health.

Stigmatization of Women's Reproductive Health:

Menstrual Stigma

Even though the study of OB-GYN and women's sexual health is at an all-time high, it still is being stigmatized and largely undiscussed by most of society. Sexual stigmatization is a massive global problem that has become normalized. There are many different forms of stigmatization but one of the main ones is the menstrual stigma. The menstrual stigma is the belief that menstruation is inherently negative or wrong and that those who menstruate are "abnormal."¹² Menstruation is often not addressed properly in society and the menstrual stigma is also not addressed.¹² One study found that no policies in the United States actively addressed the menstrual stigma and only one-third of them addressed menstrual education.¹² The lack of awareness in policies reflects and funnels modern-day society's stigmatization. With laws like "Don't Say Period," a law in Florida that restricts K-12 from talking about common reproductive health,¹³ an unfair stigmatization over periods is bound to happen. Government policies also offer no transparency as to what goes into menstrual products.¹⁴ The FDA classifies tampons as a "medical device" and only requires basic labeling for the package.¹⁴ There is no requirement for more detailed information on tampon ingredients.¹⁴ All of these policies are vague in addressing periods, menstrual stigmatization, and giving the information to the consumer. The lack of awareness of these policies is a reflection of the lack of awareness in society today.

Not only policies but also the minds of women reflect on years of menstrual stigmatization. Author McHugh has created the term "menstrual moaning" to describe people's, specifically women's, negative communication about menstruation.¹⁵ Negative communication has stemmed from a cultural taboo around periods that causes women and girls to develop shame over discussing periods. As one interviewee puts it, "Because they were suffering and they didn't know who to talk to, because this was kind of taboo, and they were ashamed to talk about that with a teacher or their mother."¹² This is seen in studies that have found that most people find it awkward to talk about periods.¹² Even when periods are talked about and represented in the media, they are discussed in a negative light and further funnel harmful stereotypes.¹⁵ The lack of proper discussion and representation leads to stress and shame in women and girls of all ages.

One of the biggest problems that the menstrual stigma can cause is miscommunication or lack of communication about menstruation. Both girls and boys suffer from a lack of proper education about menstruation. One 2007 study found that many girls felt ill-prepared to have their menarche.¹⁶ Other similar studies seemed to have found similar results. Likewise, boys have also been given little knowledge about menstruation.¹⁷ Boys have been found to often have false knowledge or limited knowledge about menstruation.¹⁷ Even though their knowledge is limited, boys seem to want to learn about menstruation but have not been allowed to do so.¹⁷ The lack of knowledge given to both boys and girls creates harmful stereotypes and policies that continue to funnel the lack of knowledge. The stigmatization of menses is a cycle running on cultural taboos to create never-ending misconceptions.

Stigmatization of Sexual Organs

Similarly, the stigmatization around discussing sexual health and organs has existed for a very long time. Many women feel awkward discussing their sexual organs and a study by Midwifery found that over half of all women felt nervous to go to an OB GYN and undergo a pelvic examination.¹⁸ It's been found that women receive little information about how the pelvic exams will take place which leads to feelings of embarrassment and worry.¹⁹ Women felt awkward not only during the exam but also discussing sexual health with this health care provider. Many surveys have found that women did not discuss their sexual health with their healthcare providers because they felt embarrassed.¹⁹ In one study, almost 25% of the participants did not discuss their sex life with their doctor.²⁰ The feeling of anxiety and embarrassment when discussing sexual health and sex is common but it should not be.

Similarly, the “taboo” around sexual health is seen in the words used to describe reproductive organs. As children, many different words were used to describe the reproductive organs. Words like “no-no square” and “privates” do not sound innately bad but they reinforce the stigmatization around genitals. These alternate names make it sound like penis and vagina are bad words when in reality they are just parts of the body. A recent study showed how the vagina is constantly censored and avoided in the media.²¹ It's been censored in social media as seen when Facebook removed the “Legalize Vagina” movement video in November 2016 and was censored in Politics with Lisa Brown being barred from speaking on the house floor because she said “vagina.”²¹ There are numerous more cases like these and the point stands.²¹ Without accepting the term vagina, there will be no future for fixing the current stigma around sex and sexual health.

Conclusions

Overall, the history of OB-GYN has been a grueling, long process to get to where it is today. With its numerous ups and downs, obstetrics and gynecology have reached further heights than ever before in history. Regardless of this, there are several ways to improve starting with helping end the stigmatization of women's reproductive health. From menstrual stigmatization to the banned use of "vagina", women's health is considered “taboo” which creates a dearth of knowledge on these subjects. Redefining unclear policies, teaching menstrual health to both boys and girls more in-depth, and using the proper terms for genitalia are all ways that help reduce the knowledge gap of women's health. By helping spread knowledge, it helps advance both obstetrics and gynecology and improves the quality of visits at the OB-GYN for both patients and doctors.

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Exploring Speech Disfluencies: An Investigation into Atypical and Typical Patterns, Genetic and Neurobiological Factors, and Psychological Responses By Sathvega Somasundaram

Abstract:

With stuttering's vast spectrum of different factors and forms, this review paper focuses on the impact of genetic, neurobiological, and psychological factors on this phenomenon, with varying brain activity among stutterers. With respect to the types of disfluencies, their frequencies, and patterns, this paper examines their developmental, neurogenic, and psychogenic aspects. The causes of stuttering, encompassing genetic factors and neurobiological effects, are explored with an emphasis on the role of non-coding regions in DNA. The implications of neuroimaging technologies display altered patterns within the neural circuitry associated with speech production and motor control, and highlight the impact of emotional stress on brain regions. Exploring family heredity with a specific focus on twins investigates the role of specific genes that influence speech development and contribute to stuttering. Presenting a review of the current literature neuroimaging, genomic, and brain studies, this paper aims to contribute to a broader spectrum of other speech disorders, overall raising awareness of stuttering among both professionals and the public. This paper aims to deliver a deeper understanding of a topic that is not as researched as others and sheds light on the various components that affect stuttering in many ways.

I. Introduction

Stuttering, a speech disorder characterized by disruptions in speech motor behavior resulting in sound and syllable repetitions, along with prolongation of certain sounds, encapsulates the vast nature of stuttering, highlighting its impact on both verbal communication and the broader dimensions of affected individuals. (Max et al., 2004)

The prevalence and impact of stuttering underscores the significance of understanding the far-reaching consequences of this speech disorder. Stuttering is not a phase of language development; rather, it affects individuals across their lifespan, presenting unique challenges in various aspects of daily life in academic, professional, and social spheres. Here, the paper will discuss speech disfluencies and the types of stuttering, along with the various factors that cause them.

I. Understanding Speech Disfluencies

A. Definition and Types of Disfluencies

Speech disfluencies refer to breaks or disruptions in speech experienced by a speaker. A common example is stuttering; overall, such disfluencies are often categorized as typical and atypical. Atypical disfluencies occur when individuals experience abnormal speech rhythms, behavioral changes, or certain interruptions. It mainly covers the rhythm and repetition of speech, hesitations with speech, and prolongations. (American Speech-Language-Hearing

Association [ASHA], 1993) An example of atypical rate/rhythm is the repetition of a sound, syllable, or word during speech. Similarly, hesitation, often intensified by tension and secondary behaviors (facial grimaces, eye blinking, abnormal body movements, avoiding speaking in situations they find difficult to say) during a conversation, may be marked by fillers and interjections such as “um,” “uh,” and “like” as well. Along with repetitions, the use of fillers, and hesitations while speaking, prolongations involve the stretching or extent of sounds, syllables, or vowels for a period of time.

Typical disfluencies, often recognized through revisions (where the speaker rephrases or corrects themselves mid-sentence), repetitions (repeating short phrases for emphasis or clarification), and incomplete phrases, can occur or last for any period and usually do not raise particular concerns in terms of treatment or the need for intervention. Common among children are typical disfluencies because of fatigue, excitement, or unhappiness.

B. Frequency and Patterns

One fundamental aspect of studying speech disfluencies is focusing on the frequency in spoken language. Frequency analyses showed that fillers (e.g. "uh" and "um"), repetitions, and revisions, often appear 50-100 times in conversions with atypical disfluencies, also visualized in Figure 1. (Gregg et. Al., 2012) If we refer to Figure 1, we can see the correlation between age and the percentage of stuttered syllables in a stuttering episode. Different types of disfluency may exhibit distinct patterns across contexts and discussions. For instance, filled pauses are more prevalent in spontaneous, unscripted speech, while repetitions and revisions are more common in speech that requires problem-solving or storytelling.(Redford, 2012)

Additionally, the distribution of speech disfluencies varies among specific areas, especially with studies indicating that disfluencies tend to cluster at specific points in a sentence such as the beginning, end, or even during specific points of a sentence in a different language due to their orthographic transparency.

Percentage of stuttered syllables vs Age

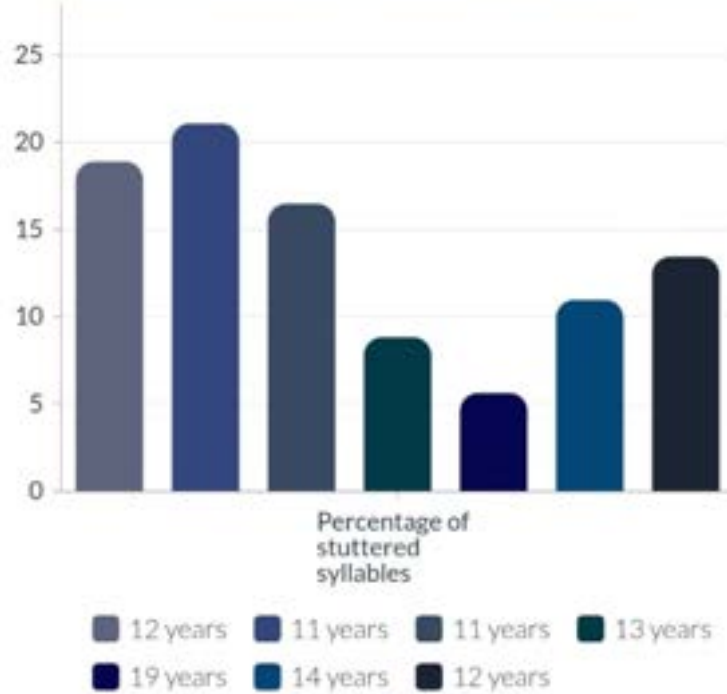


Figure 1: (Jani et al., 2013)

Age	Gender	Percentage of stuttered syllables
12	F	18.9%
11	F	21.09%
11	M	16.48%
13	M	8.83%
19	M	5.56%
14	M	10.97%
12	M	13.45%

II. Types of Stuttering

Referencing Figure 2, all the speech disfluencies and can be portrayed in an organized manner.

A. Developmental Stuttering

1. Characteristics

As developmental stuttering is an atypical disfluency, many of its characteristics are along the lines of disruptions in typical speech flow, repetitions, prolongations, or blocks (which correlate with hesitation and tension). Stuttering may vary from child to child in severity and can be influenced by many situational factors. Some examples include language, where certain languages require different phonetic abilities; environment, where negative feelings or emotions

increase tension; and brain function, where areas of the brain responsible for language and speech look and work differently in people who stutter. (Singer et al., 2020)

2. Prevalence in Children and Adults

Developmental stuttering is most common among young children, especially new speakers, because it occurs when a child's speech and language abilities do not meet their verbal capabilities. While many children outgrow stuttering naturally, some may require intervention to reduce its impact on communication and social interaction.

Developmental stuttering is an atypical disfluency that is not as prominent during adulthood; thus, there have been major differences between stuttering in adults and children. Reduced or abnormal activity in auditory-associated areas, increased activity in the right frontal and left cerebellar regions (related to stuttering), deficiencies in left gray matter volume, reduced white matter in the left hemisphere, and irregular timing between motor regions in the left hemisphere of the brain are all present in persistent stuttering seen in adults. (Chang et al., 2007) Asymmetries in the brain structure of adults may result in functional differences and play a role in handedness (Buchel et al., 2004), language literacy, bilingualism (Nucifora et al., 2005), and instrument practice (Gaser and Schlaug, 2003).

B. Neurogenic Stuttering

Neurogenic stuttering is defined as a type of stuttering in which the disfluencies associated with brain damage or injury lead to disturbances in the typical function of the brain in those who do not stutter. (Junuzovic-Zunic et al., 2021) Unlike developmental stuttering, which mostly occurs in children, neurogenic stuttering can occur at any age because of neurological impairment. Distinct characteristics of neurogenic stuttering, such as uncontrollable speech rate, long pauses, increase in repetitions (especially those of syllables and words), prolongation, and rapid speech outbursts, are similar to those of other communication disorders, including aphasia, dysarthria, apraxia of speech, palilalia, anomia, and confusion.

1. Association With Brain Lesions and Injuries (Extraneous causes)

Based on the definition of neurogenic stuttering, it is not possible for it to be associated with damage to a particular part of the brain, as rather it takes part in the neural network for fluent speech production. Similarly, the occurrence of neurogenic stuttering, especially from a stroke, is not limited to a lesion in a specific region of the brain but also correlates with the basal ganglia, lower frontal cortex, upper temporal cortex, and white matter, all of which are related to neural sensory and motor network speech.

C. Psychogenic Stuttering

1. Psychological Trauma

The roots of psychogenic stuttering are often traced back to psychological trauma, in which individuals experience events or circumstances that have a lasting impact on their mental

well-being. Traumatic experiences resulting in severe emotional distress, can manifest in psychogenic stuttering as a psychosomatic response, especially since individuals grapple with their emotional and cognitive challenges associated with such memories. As a rare speech condition, this form is characterized by rapid repetition of sounds and words during speech.

Psychological trauma often involves the formation of traumatic memories that may be linked to speech and communication. The structured response to trauma can manifest in speech disruptions, as individuals grapple with the emotional and cognitive challenges associated with such memories.

2. Association with Stress and Anxiety

Stress and anxiety can exacerbate or trigger episodes of psychogenic stutter. The disorder often presents itself during periods of heightened stress or emotional turmoil. The association between stress and psychogenic stuttering suggests a direct link between an individual's psychological state and the occurrence of speech disruption. The anticipation of potential stressors or anxiety-inducing situations, such as increased muscle tension and altered respiratory patterns, can directly influence articulatory and phonatory aspects of speech.

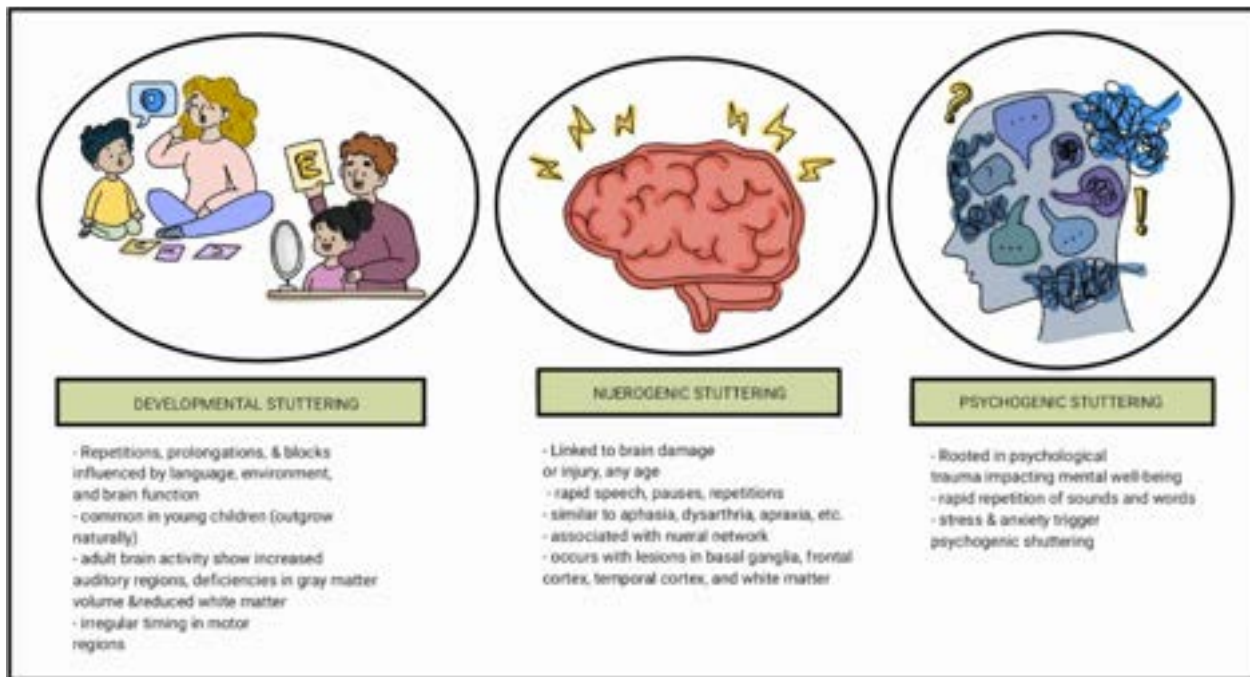


Figure 2: The figure shows the kinds of stuttering (Developmental, Neurogenic, and Psychogenic) and share their characteristics

III. Causes of Stuttering

A. Genetic Factors

Heredity plays a major component in stuttering, allowing for a deeper outlook into its mechanisms. Family and twin inheritance has shown a higher prevalence of stuttering among

first-degree relatives, indicating a genetic predisposition. Genetic factors consist of many components, many of which are causative mutations and ancestry of the population.

Exploring the genetic factors underlying stuttering has revealed a novel dimension with a focus on non-coding regions of DNA. Recent research has revealed that these non-coding regions harbor a substantial proportion of risk alleles associated with stuttering. (Benchek et al. 2021) In the context of genetic regulation, non-coding regions play a pivotal role in the intricate regulation of gene expression. Notably, the risk alleles identified in these noncoding regions manifest incomplete effects and do not adhere to traditional patterns of inheritance.

This discovery challenges the conventional genetic model, as it underscores the significance of parts of the DNA that do not explicitly provide instructions for protein synthesis. The variations housed in these noncoding regions have been linked to susceptibility to certain conditions or diseases, shedding light on why some individuals are more prone to stuttering. Recognizing the impact of noncoding regions in our genetic makeup not only deepens our understanding of the genetic basis of stuttering but also underscores the broader implications of these regions in influencing health and predisposition to speech sound disorders.

1. Family Heredity

In twin families, twins are prone to stutter more frequently than single-sibling members, as established by one twin child in 11 cases of stuttering, whereas only one in 35 cases (in single siblings). Since identical twin pairs share all of their DNA, while non-identical twins share only half (similar to non-twin siblings), looking into identical and fraternal twins, the identical twin concordance for stuttering is 20% higher than that of fraternal twins. This relationship means that the factor in germplasm-producing twins may be the gene that results in the correlation between abnormal development of polarity in an embryo, which affects the production of normal speech. (Kraft et al. 2011)

Extended families (including parents, siblings, and grandparents) have a higher probability of stuttering than nuclear families (only parents and children), and many of the genes that are affected by speech impediment include FOXP2, a known gene that is associated with speech disorders (e.g. verbal dyspraxia), CNTNAP2, and KIAA, which are genes that affect phonological/expressive aspects, DACT, an excitatory synapse organization and dendrite formation during neuronal differentiation, and chromosome 18, which has the most relevant impact on those who stutter. (Benchek et al. 2021)

Chromosome 18, specifically, has a relatively large area, as it consists of clusters of genes belonging to desmoglein and cadherin. These two genes play important roles in cell adhesion, intercellular communication, and hearing impairment, all of which are relevant to the production of speech.

B. Neurobiological Aspects

Stuttering is closely linked to aberrations in the structure and function of the brain. Neuroimaging techniques, such as Magnetic Resonance Imaging (MRI) and Functional Magnetic

Resonance Imaging (fMRI), have revealed differences in the neural circuitry of individuals who stutter. Figure 3 displays the relationship between all neurobiological aspects, along with the roles they take part in.

1. Brain Structure and Function

Investigating the neurobiological aspects of stuttering has revealed intricate relationships between brain structure and function. Stuttering, characterized by disruptions in speech fluency, is associated with a breakdown in the integration of auditory data during the planning of speech motor activities. Notably, connectivity analyses showed a significant reduction in the connections between the left inferior frontal gyrus (IFG) and basal ganglia in individuals with stuttering. (Gajbe et al., 2022) This reduction points towards a key neural substrate for the manifestation of stuttering, suggesting that compromised communication between these brain regions contributes to the disorder's characteristic speech interruptions. (Benček et al. 2021)

Further exploration into the brain regions implicated in stuttering extends to Broca's region, where decreased perfusion and indicators of neuronal density have been identified. (Desai et al., 2016) This finding suggests that the neural underpinnings of stuttering go beyond mere connectivity issues involving alterations in regional blood flow and neuronal composition. Interestingly, the impact of stuttering on speech fluency is not uniform across all linguistic activities, with spontaneous speech being affected more than conversation, reading, sentence repetition, or singing.

The dual-process theory of language formation offers a valuable framework for understanding the neurobiological basis of stuttering. According to this theory, the basal ganglia plays a crucial role in handling formulaic phrases, while the left hemisphere is essential for constructing innovative, freshly constructed sentences. (Gajbe et al., 2022) fMRI studies have supported these theoretical foundations by revealing decreased frontal lobe activity in the inferior frontal gyrus of adults with stuttering.

In addition, the left language-dominant brain hemisphere, which is traditionally active during speech and language tasks, exhibits abnormal dominance in individuals who stutter. Early studies using electroencephalogram (EEG) lateralization techniques strongly suggest atypical brain lateralization patterns in stutterers.

2. Neuroimaging:

Functional brain imaging studies have revealed altered patterns of activation and connectivity within regions closely tied to speech production and motor control. (Chang et al., 2009) These images not only capture the dynamic aspects of stuttering but also provide a foundation for developing interventions grounded in neurobiological understanding.

Neurochemical investigations have linked stuttering to disorders within a network of structures that control movement, particularly in the basal ganglia. (Gajbe et al., 2022) Notably, an increase in the neurotransmitter dopamine, which is associated with movement disorders such

as Tourette syndrome, has been identified, suggesting a role for the dopaminergic neurotransmitter system in stuttering. (Büchel et al., 2004)

3. Correlations with Psychological Factors

fMRI scans have revealed altered activation patterns in regions associated with emotion regulation and speech production in individuals who stutter. Specifically, heightened emotional stress has been correlated with increased activity in the amygdala, a key brain region involved in emotional processing. (Zengin-Bolatkale et al., 2018)

Additionally, the prefrontal cortex, a region associated with executive function and emotional regulation, has shown differential activation in response to emotional stress in individuals who stutter. The intricate balance between the prefrontal cortex and limbic system, which includes the amygdala, appears to be disrupted during emotionally charged episodes, potentially contributing to increased speech disfluency. (Girotti et al., 2017)

Studies using positron emission tomography (PET) scans have indicated alterations in neurotransmitter systems, particularly those involving dopamine, in individuals who stutter under emotional stress. Dopaminergic pathways, which play a role in emotional responses and motor control, may be dysregulated in individuals with stuttering. (Alm, 2021)

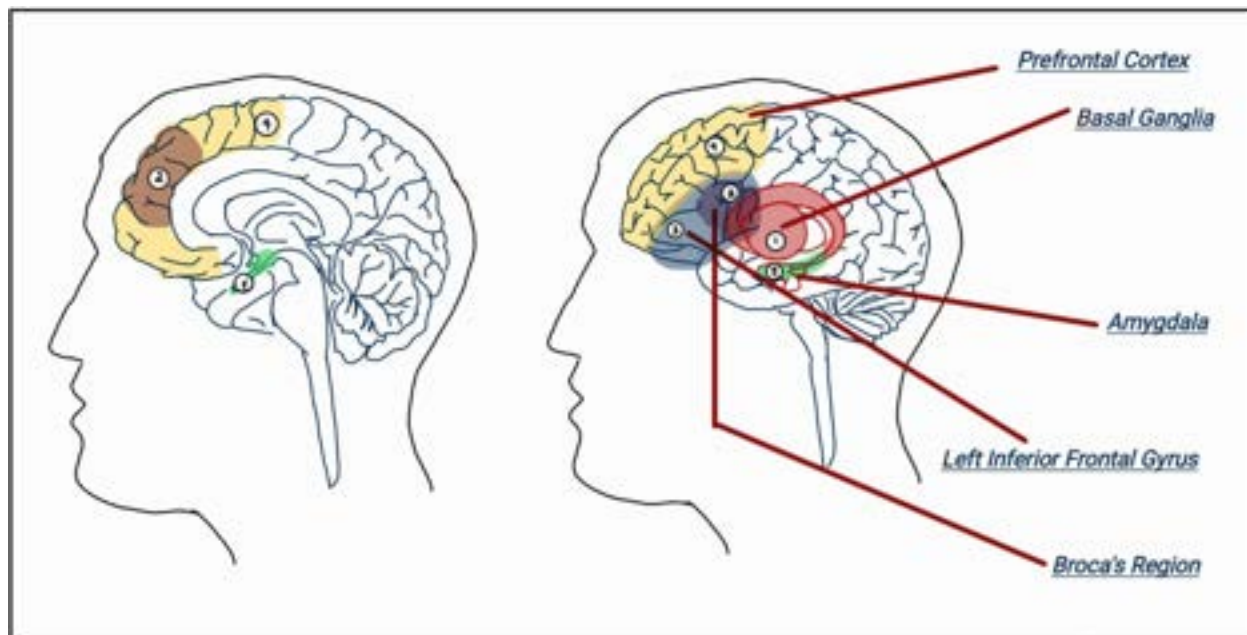


Figure 3: The Left Inferior Frontal Gyrus (IFG) is mainly involved in planning speech motor activities. It also has a reduced connectivity in individuals with stuttering, indicating a key neural substrate for the disorder. The Basal Ganglia is crucial for handling formulaic phrases. There is decreased connectivity with the left IFG observed in stuttering individuals, suggesting its involvement in speech disruptions. The Broca's Region predominantly associated with language formation. Similarly, it also has decreased perfusion and altered neuronal density in individuals

with stuttering, indicating its role in speech fluency. The Amygdala is involved in processing emotions and has heightened activity during emotional stress in individuals who stutter, suggesting a correlation with increased speech disfluency. The Prefrontal Cortex is associated with executive functions and emotional regulation. It shows differential activation in response to emotional stress in individuals who stutter, potentially contributing to speech disfluency during emotionally charged episodes.

C. Psychological Factors

1. Behavioral and Environmental Influences

Avoidance behaviors such as word substitutions or circumlocutions (the use of many words where fewer would do) may become ingrained over time and affect neural plasticity. Functional neuroimaging reveals distinct neural signatures associated with these learned behaviors, indicating that the brain undergoes adaptive changes as individuals navigate stuttering challenges.

Early experiences that include negative responses to stuttering may contribute to the development and persistence of stuttering behavior. Additionally, environmental stressors such as high-pressure communication situations can trigger or worsen stuttering. Stigmatization and negative societal attitudes can induce biological changes in individuals. Chronic exposure to negative reactions leads to heightened stress responses that trigger changes in the neuroendocrine system. Elevated cortisol levels, which are indicative of increased stress, have also been observed in individuals who stutter during communicative situations. (Blood et al., 1997)

D. Psychological responses to stuttering

1. Emotional and Psychological Stress

Individuals who stutter may experience heightened anxiety and emotional tension, particularly in communicative situations, which contributes to increased speech dysfluency. The fear of stuttering, commonly known as anticipatory anxiety, can become a pervasive emotional undercurrent that affects individuals in communicative situations. This emotional and psychological stress can create a self-reinforcing cycle, where the fear of stuttering leads to increased anxiety, subsequently exacerbating speech disorders.

Individuals who stutter may develop maladaptive thought patterns and coping mechanisms in response to the challenges posed by their speech disorders. Negative self-perceptions and social anxiety can further intensify the psychological stress experienced by individuals who stutter.

With these challenges, the mechanisms underlying stuttering and its psychological ramifications is crucial to understand. The brain's capacity for plasticity and adaptive learning comes to the forefront in understanding how psychological responses to stuttering mold neural pathways over time. Behavioral responses to emotional stress, such as avoidance behaviors, become ingrained through adaptive learning mechanisms that shape the neural circuits associated with speech production and emotional regulation (Figure 4).

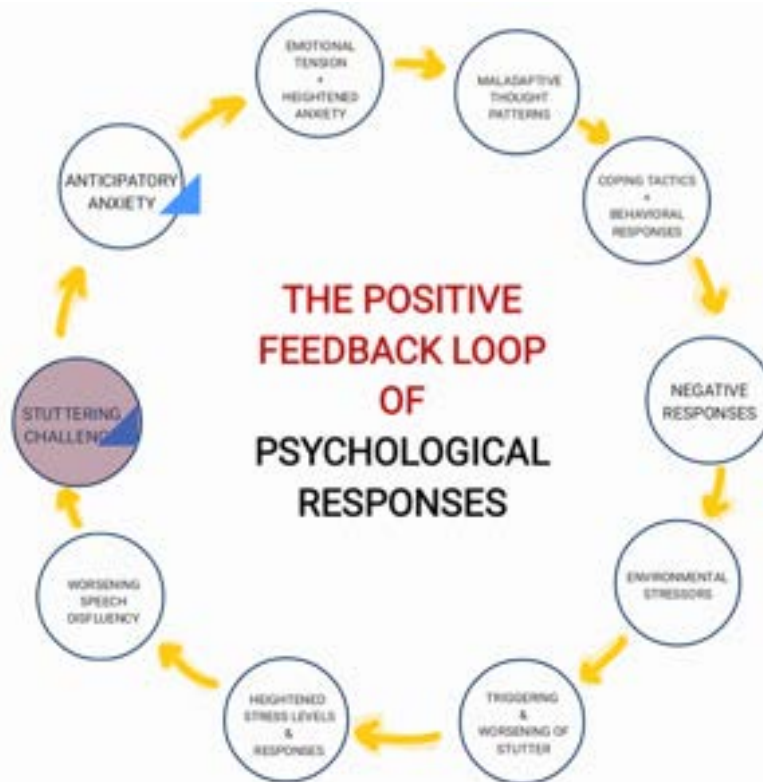


Figure 4: The feedback loop above shows the cycle of psychological responses towards a stuttering episode

Conclusion

The examination of frequency and patterns reveals distinct characteristics of atypical disfluencies, such as filled pauses, repetitions, and revisions, occurring more frequently in specific contexts. Frequency analyses revealed distinct patterns in atypical disfluencies that varied across contexts. Stuttering, which takes many forms, is often organized as developmental, neurogenic, and psychogenic stuttering, presenting various factors influencing its occurrence.

Genetic exploration, particularly in noncoding regions, also challenges the role of noncoding DNA in individuals who stutter. With the employment of neuroimaging technologies, altered patterns of activation and connectivity within the neural circuitry are displayed, along with the impact of emotional stress on brain regions. Family heredity, with a focus on twin and extended families, sheds light on specific genes, such as FOXP2 and Chromosome 18, implicated in stuttering.

Psychological responses to stuttering, including emotional stress and learned behaviors, contribute to a self-reinforcing cycle that shapes the neural pathways. With a specific focus on neuroimaging techniques, they showed the correlation between the basal ganglia and the left hemisphere throughout a stuttering episode.

As a whole, the role of genetic, neurobiological, and psychological factors in speech disfluencies provides a comprehensive perspective of stuttering, offering valuable insights for future research and interventions.

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Enhancing Financial Decision-Making : AI-Driven Forecasting of Stock Market Prices

By Harman Suri

Abstract

In this investigation, machine learning models including Linear Regression, Neural Networks, and Decision Trees were leveraged to forecast stock prices using historical data sourced from Yahoo Finance. This study aimed to overcome the challenges of data collection and processing, feature engineering, and model optimization to effectively predict stock prices, a key determinant in financial market strategies. Through rigorous evaluation using error metrics like Mean Squared Error (MSE), models were compared and analyzed for performance. Results demonstrated varying efficacy across different models, with the combined methods showing superior accuracy, underscoring their potential in real-world application for trading strategy improvement, investment risk management, and portfolio diversification. The research findings also emphasized the significance of recent market trends in price predictions and the necessity for incorporating a broader range of datasets for enhanced predictability. Despite facing challenges such as market unpredictability and historical data dependency, this study sets the stage for further exploration in real-time market analysis and the ethical implications of AI in financial Decision-making. Interestingly, when applied to predict Google's stock prices, the best-performing model achieved an MSE of 3.75, and the deployment of a trading bot based on these predictions resulted in a simulated portfolio performance increasing from \$10,000 to \$16285. These results showcase the potential for AI-enhanced trading systems to improve market strategy, risk management, and portfolio diversification.

Introduction

The quest to decode the future of stock prices represents not only an economic interest but a sophisticated analytical challenge that has intrigued economists and mathematicians for centuries. With the stock market's origins dating back to the late 16th century, its evolution into a complex and dynamic entity reflects the broader shifts in our global economy. The advent of the public stock exchange, a seminal event marked by the Amsterdam Stock Exchange's establishment in 1602, laid the groundwork for modern financial markets and the concept of publicly traded companies.

The modern stock market, characterized by its volatile nature and susceptibility to a myriad of factors ranging from economic indicators to investor sentiment, presents a fertile ground for the application of artificial intelligence (AI) and machine learning (ML). The AI revolution has ushered in a new era in stock market forecasting, where the traditional statistical methods are being augmented—or in some instances, supplanted—by AI-driven models capable of digesting vast amounts of data to unearth predictive insights.

This study, titled "Enhancing Financial Decision-Making: AI-Driven Forecasting of Stock Market Prices," steps into the vibrant intersection of finance and AI. It builds upon the foundational work of noted studies such as "Stock Market Prediction via Deep Learning Techniques: A Survey," which maps the trajectory of deep learning applications in market

predictions, and "Short-term Stock Market Price Trend Prediction Using a Comprehensive Deep Learning System," which explores the efficacy of ensemble methods in short-term price prediction. Moreover, studies like Jeon et al.'s work on high-frequency trading data analysis exemplify the innovation in employing big data for market trend analysis.

In bridging the existing knowledge gap, our project goes a step further by synthesizing various AI techniques—namely, Linear Regression, Neural Networks, and Decision Trees—to craft a robust model that not only predicts stock prices with greater accuracy but also provides a deeper understanding of the market's underlying mechanisms. This integrative approach not only taps into the individual strengths of each method but also orchestrates them into a symphony of predictive analytics, enhancing the overall accuracy and reliability of stock market forecasting.

Our research navigates through the historical data, provided by a reliable source like Yahoo Finance, and weaves it into a predictive model that aims to serve as a beacon for investors and traders alike. By doing so, it contributes a novel perspective to the academic conversation around financial forecasting and extends the frontier of AI application in stock markets, thereby holding the potential to transform financial decision-making processes significantly.

Methods

In this project, we deployed three primary models, each selected for its strengths in modeling financial data trends and patterns.

Linear Regression: This model predicts future stock prices based on a linear relationship with the last 4 days of historical prices. It operates under the assumption that past price movements are indicative of future trends. The input for this model was a series of the last 2, 3, or 4 opening stock prices, aiming to predict the opening price of the following day.

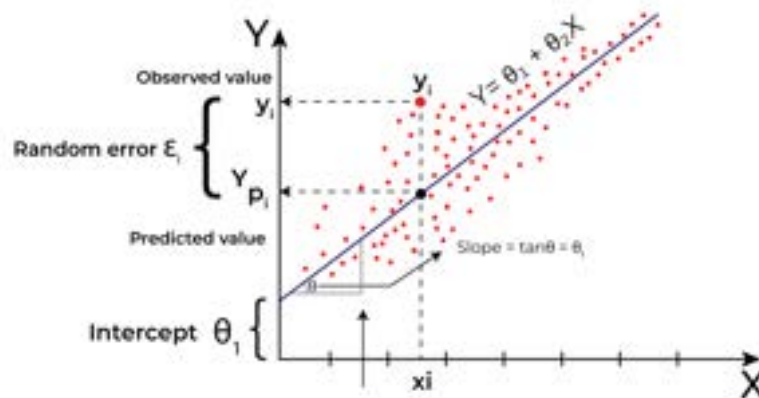


Fig 1.1: Linear Regression model

Neural Networks: This more complex model can capture intricate patterns in the data that may not be apparent or accessible to simpler models. It processes the same inputs as the Linear Regression model but through multiple layers and neurons, allowing for the identification of non-linear relationships.

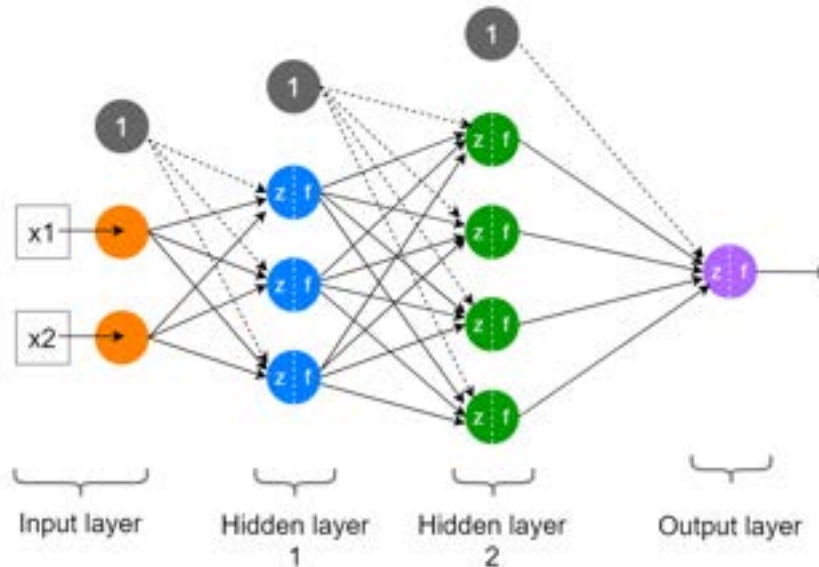


Fig 1.2: Neural Network model

Decision Trees: This model provides a flowchart-like structure that helps in making decisions based on the historical data provided. They are valuable for their interpretability and are trained using the same input features as the other models, with the output being the next day's price.

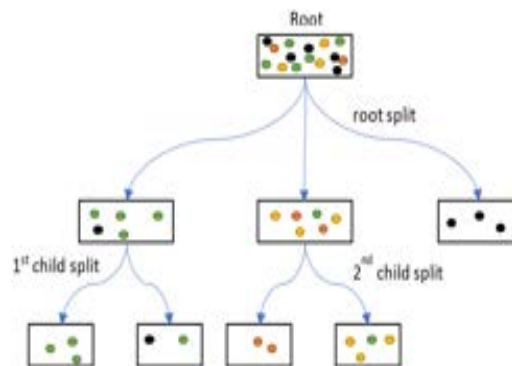


Fig 1.3: Decision Tree model

The combined model: This model takes into account 2 models (Linear Regression and Neural Networks) due to their relatively better MSE results. This combined model utilizes the Multiplicative weight update (MWU) to assign weights to the Models. The Multiplicative Weight Update strategy is pivotal to this combined model. MWU is an algorithmic technique that adjusts the weights of the individual models based on their prediction accuracy. By doing so, the combined model becomes a dynamic system that evolves based on performance, emphasizing the contributions of more accurate models over those less precise.

How does the MWU work?

Initial Setup: Both models start with equal weights.

Performance Evaluation: After each prediction, the Mean Squared Error (MSE) metric evaluates the accuracy of predictions from each model.

Adjusting Weights: The MWU algorithm updates the weights of each model inversely proportional to their MSE scores. Models with lower MSE, indicating higher accuracy, have their weights increased, whereas those with higher MSE see their weights decreased.

Update Formula: The weight adjustment is calculated using $\text{Weight} = \text{weight}/\text{error}^2$ which normalizes the weight so they sum up to 1. The final weight for the stock “JPM” was 0.99 weightage on the Linear regression model and 0.01 weightage to Neural Networks.

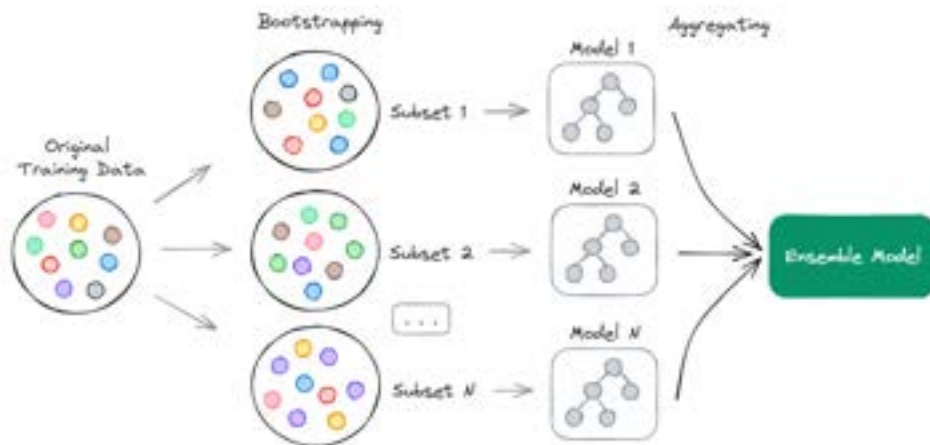


Fig 1.4: Combined model

Fig 1.4 showcases several models being aggregated into a larger ensemble/combined model. This is similar to how the combination of the two models above worked. There is no cap to the number of models that can be combined, therefore in the same manner the MWU will assign weightage to the models. The MWU will also discard models that are not accurate by assigning a 0 weight after a duration time. Models that are more inaccurate will reach 0 weight sooner. This method encourages the usage of more models due to its ability to assign 0 weight to inaccurate models.

Trading Bot

The trading bot was a practical application built on the predictive models, designed to simulate trading decisions. It used the models' outputs to make buy and sell decisions based on the prediction of price movements. The bot's algorithm was simple: buy if the price was predicted to rise and sell if it was expected to fall. The current trading bot takes into account only one company and in the future it can be designed in a way to take into account more than one company at a time.

Dataset

Data was sourced from Yahoo Finance, which provided an extensive library of stock data for the last 5 years. This data was then split into a training set (67%) and a testing set (33%) to evaluate the models' performance on unseen data. The training involved feeding historical price data into the models and adjusting their parameters for optimal performance.

While we had access to various types of stock price data such as opening, closing, high, and low prices, we chose to primarily focus on opening prices for our predictive models. One significant reason for excluding high and low prices from our primary analysis is their transient nature within the trading day. Specifically, the high price of a stock can be reached briefly, lasting only a second or so, before changing. This brief peak does not necessarily provide a stable indicator of the stock's value or its direction. Similarly, low prices might reflect momentary dips rather than sustained trends, making them less reliable for predicting future prices.

Focusing on opening prices offers a more consistent baseline for analysis. Opening prices reflect the market's initial reaction to news and events since the last close, which can be a more stable indicator of market sentiment and trends. By concentrating on these values, our models aim to utilize data that best represents consistent market behavior, improving the reliability of our predictions.

The models were evaluated using Mean Squared Error (MSE), which measures the average of the squares of the errors—i.e., the average squared difference between the estimated values and the actual value. A lower MSE indicates a model with a better fit to the data.

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

Fig 1.5: Mean Square Error Formula

Why Is This Project Important?

The project's findings are particularly relevant to investors and traders, offering a potential tool for enhanced decision-making. By understanding past values and employing AI to predict future market behavior, there is a promise of improved investment strategies and risk management.

This project's importance extends beyond financial gains, touching on the broader implications of AI's role in economic forecasting and market stability. It not only provides a foundation for more sophisticated trading algorithms but also contributes to our understanding of market dynamics. Ultimately, it highlights the transformative potential of AI in finance, suggesting a future where technology and economics are increasingly intertwined, driving towards more informed and efficient markets.

Results

In this study, the application of AI-driven models to the task of stock price prediction yielded quantifiable and actionable insights. The results are as follows

Companies	Models' MSE			
	Linear Regression	Neural network	Decision Tree	Combined
Tesla	63.51	67.46	104.60	63.61
Microsoft	21.07	25.03	42.56	21.11
Google	3.75	5.58	7.13	3.80
JP morgan	3.73	4.35	9.61	3.75
Nike	7.01	8.70	12.00	7.02

Linear Regression Model: This model returned a Mean Squared Error (MSE) of 3.73 for JP morgan, indicating a good level of accuracy in predicting stock prices.

Neural Network Model: The Neural Network model showed a higher MSE of 4.35 and demonstrated a moderately accurate model to the data and a weaker predictive capability compared to the **Linear Regression** model.

Decision Tree Model: The Decision Tree algorithm had a variable performance with an MSE of 12, which was significantly higher than both **Linear regression** and **Neural Networks**.

Company (Ticker Symbol)	Starting Budget (\$)	Ending Budget in 5 years (\$)
JPM	1000	1722.81
JPM	2000	3208.71
JPM	5000	8138.98
JPM	10000	15238.45
AAPL	1000	4255.34

AAPL	2000	8186.90
AAPL	5000	20037.47
AAPL	10000	36567.76

Trading Bot Performance (Using Neural Network): When the trading bot was deployed with an initial investment of \$2000, it resulted in an end balance of \$3200, showcasing the practical value of the predictive models.

The performance metrics across different companies varied, indicating that the model's effectiveness could be influenced by individual stock characteristics or market conditions. Detailed figures for each company tested will be provided by the author.

These results provide a benchmark for the efficacy of different AI models in the context of financial decision-making and pave the way for further research into the integration of machine learning in stock market analysis. The author will fill in the specific data points and visual representations upon finalizing the study.

Conclusion

The exploration into the predictive power of AI for stock market prices has culminated in a significant understanding of how various models perform with real-world data. The results have underscored the nuanced capabilities of machine learning, with Linear Regression and ensemble methods outperforming simpler models like Neural Networks in complex market dynamics. The practical application of these findings through a trading bot has further demonstrated the potential for AI to inform and enhance investment strategies, leading to profitable outcomes.

The implications of this study are far-reaching. For investors and market analysts, the integration of AI into trading strategies could mean more informed decision-making, improved risk management, and optimized portfolio management. The research also opens the door to the broader application of AI in financial markets, suggesting that data-driven, automated systems could become integral to future market analysis and trading operations.

However, the study also revealed limitations, such as the susceptibility of models to market volatility and the reliance on historical data. These insights present open questions for further research, such as the integration of real-time analysis and broader data sets including financial reports, economic indicators, and global market trends, which could enhance the accuracy and robustness of predictions. Analyzing the correlation and interdependence of company stock prices on each other, which could help understand the relationship between different companies stock prices and if they are related how can this be used to predict future prices.

For those looking to continue this research, a promising avenue would be the incorporation of machine learning techniques that can adapt to new data in real-time, perhaps utilizing streaming data platforms for a more dynamic and responsive model. The exploration of

how company-specific financial reports influence stock prices would also be valuable, providing a more granular perspective on the interplay between company performance and stock market response.

This study serves as a testament to the evolving relationship between AI and financial markets, marking a step towards more sophisticated, data-driven investment approaches that could redefine traditional market methodologies.

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The Moral Limit of Genetic Enhancement of Human Beings: Ethical Implications and Controversies

By Nina Morozova

Abstract

This research paper explores the moral limit of genetic enhancement in humans, considering its potential consequences and ethical implications. The paper evaluates the interplay of power dynamics within society, the aspect of customization in human aesthetics, and concerns regarding human traits. It discusses the potential for genetic enhancement to exacerbate social inequalities, erode individual choice and autonomy, and perpetuate unrealistic beauty ideals. The paper critically examines arguments in support of genetic modification and advocates for emphasizing the ethical use of genetic modification exclusively for treatment purposes rather than enhancement.

Introduction

Genetic modification is usually thought about in the context of agriculture or livestock farming. Better crops that survive diseases which would be devastating to their unmodified counterparts or for pigs and sheep with a higher growth rate; Although such technologies are becoming widespread their uses on human being i highly controversial So in this paper i will attempt to answer the question: "What is the moral limit of genetic enhancement of human beings?" In this exploration, we will discuss the idea proposed by this possible future. I will especially focus on the idea of genetic enhancement being used only for treatment rather than enhancement, since the latter raises serious ethical issues.

Power Dynamics and Social Disparities

Genetic modification for enhancement purposes introduces a complex interplay of power dynamics within society. At first this process has the potential to create and reinforce existing disparities, primarily favoring the wealthy and privileged, because genetic enhancement would likely be initially accessible only to the wealthy. One might argue that genetic enhancement could be harnessed to reduce inequality by providing everyone with similar abilities. In this scenario, the potential for equal access to genetic enhancement could be realized, theoretically leveling the playing field. This could be realized through government subsidies that will provide genetic enhancement for everyone else and not just the wealthy. Although for this reason people might believe that genetic enhancement can be used as an instrument of reducing differences, this vision might go too far. This notion overlooks the inevitable disparities in service quality. Wealthier individuals would likely access superior enhancements, perpetuating rather than mitigating social inequalities. "The risks here of creating greater inequalities seem to be obvious," says Todd Daly, an associate professor of theology and ethics at Urbana Theological Seminary in Champaign, Ill. "And I'm not convinced that people who get these enhancements will want to make sure everyone else eventually gets them too, because people usually want to

leverage the advantages they have.”¹ Additionally even the wealthy lose their ability to gatekeeper the , making genetic enhancement widely available risks turning it into an unspoken societal requirement, eroding individual choice and autonomy. This implicit compulsion to undergo genetic modifications for parity, not advantage, poses significant ethical concerns, potentially transforming genetic enhancement from a privilege into a societal necessity, thereby deepening existing inequalities and ethical dilemmas.

However, it has to be noted that ethical problems concerning genetic enhancements are more than just a question of narrowing down social gaps, and therefore, more comprehensive consideration about ethical discussions and regulation has to be done while considering this area. Then, as genetic enhancements become more accessible to those who can afford them, a metaphorical arms race ensues, where the privileged few possess the means to further improve themselves while leaving others behind.

Customization and Aesthetics

Genetic modification also brings into focus the aspect of customization in terms of human aesthetics. The new age has seen a growing trend toward customizing human appearance where there are ethical problems with transforming people’s bodies into consumer goods as objects intended only for outward beauty. As Kass Leon R. states in his book “Life, liberty and the defense of dignity: The Challenge of Bioethics”: "Turning our bodies into objects of perfecting through genetic modification not only commodifies our physical selves but also raises profound questions about the essence of our humanity and individuality.” Meanwhile in some sense, people may see this more as an exercise in freedom where one can say something about how they want to be perceived as well as stating an affirmation on personal identity. This argument is made on the basis of choice which people have made to change their appearance, therefore they are entitled to choose. Although one should take account of autonomy as a pertinent issue, some ethical dimensions can outweigh the significance of autonomy in at least some aspects. This could prove very serious as it involves issues such as personal autonomy and goes well beyond individual choice with consequences such as societal perception of beauty, self-esteem, and even a person's unique and separate identity. For example some drugs are illegal even though they are consumed by people freely and can be considered a part of their autonomy, however the harm it does to the person itself and the community so that autonomy may be overlooked.

Human Traits and Ethical Considerations

Concerning human traits, the issues of ethical consideration arising from genetic modification are even deeper because they touch upon the fundamental values that define and distinguish the essence of humanness. One possible concern about these interventions is that they may decrease the emotional depth in a person. Humans depend on emotions for proper cognitive activity, social interaction and making decisions. A blend of genetic and other environmental

¹ Brugger, E.C., & Daly, T. (Date Unavailable). "Human Enhancement: Scientific and Ethical Dimensions of Genetic Engineering, Brain Chips and Synthetic Blood." Pew Research Center. Retrieved from www.pewresearch.org.

factors leads to this mixture of various human emotions. Accidental disturbance of this equilibrium can be caused by interventions purportedly designed to correct genetic vulnerability to emotional responses. The loss of this diversity of feelings might also undermine the richness and reality of human experiences, leading to a narrowed emotional terrain. Brugger, E.C. in his paper "Human Enhancement: Scientific and Ethical Dimensions of Genetic Engineering, Brain Chips and Synthetic Blood." states that "Happiness is found in marriages, in families, in neighborhoods ... None of these are promised by enhancement."² This also underlines the issue that the idea of more stable and predictable emotions don't always mean that the emotional fulfillment of the person would be superior to their old emotions. In this case, there are worries that fundamental features of human identities could be threatened since feelings are closely related to objective perception of self and others. "Genetic interventions aiming at enhancing human emotions or cognitive abilities risk diminishing the diversity of human experiences, which are essential for the richness of cultural and individual identity."³ It is important to preserve the diversity of human emotions as a part of complex identity whose loss may be ethically evaluated when discussing genetic modification.

However the idea of genetic modification on humans is a very appealing notion for many people. Those individuals have several major arguments that support this notion, and in this part of the essay we will address and debunk such points. One of the most prominent points is that genetic enhancement is just another stepping stone in humanities evolution. This idea fundamentally differs from natural evolutionary processes both ethically and philosophically. Unlike evolution, which is an unguided and based on natural selection-driven process, while genetic enhancement is a deliberate, human-directed intervention, aiming to instill specific traits, thereby diverging from the random, non-discriminatory nature of natural evolution. This human intervention raises significant ethical concerns, particularly in exacerbating social inequalities and potentially introducing new vulnerabilities, as access to such technologies is likely to be uneven, privileging certain groups over others. Furthermore, from a philosophical standpoint, it challenges the essence of human dignity and individuality, which evolution inherently respects, by promoting an artificial notion of 'improvement' and 'perfection.' "The moral acceptability of genetic interventions lies not in their technical capability but in their purpose: to heal rather than to enhance, to restore rather than to perfect."⁴ Thus, equating genetic enhancement with natural evolutionary processes overlooks these crucial ethical, social, and philosophical implications, necessitating a more nuanced and critical examination of its role and impact on humanity.

Another of the arguments supporting genetic modification on humans is that it will lead to a utopian society. This assertion demands a nuanced assessment. While its potential to eliminate hereditary diseases and enhance traits is touted, oversights in this optimism include a failure to acknowledge the inherent subjectivity in defining societal perfection and the

² Brugger, E.C. (Date Unavailable). "Human Enhancement: Scientific and Ethical Dimensions of Genetic Engineering, Brain Chips and Synthetic Blood." Pew Research Center. Retrieved from www.pewresearch.org.

³ Habermas, Jürgen. *The Future of Human Nature*. Polity Press, 2003

⁴ President's Council on Bioethics (U.S.). *Beyond Therapy: Biotechnology and the Pursuit of Happiness*. Dana Press, 2003

unpredictable consequences of technological progress. The assumption of a uniform ideal neglects the richness of individual perspectives, while historical precedents underscore the potential for exacerbated social disparities and new forms of discrimination. Ethical concerns surrounding consent, autonomy, and the misuse of genetic information must be carefully considered. A comprehensive evaluation of the impact of genetic modification on societal structures and values is imperative before embracing it as a harbinger of utopia. For these reasons it may be more prudent to use genetic modification technologies exclusively for treatment purposes rather than enhancement purposes.

Conclusion

In wrapping up the ethical debate on human genetic enhancement, we have examined the difference between treatment and enhancement. “Some researchers and bioethicists are concerned that any genome editing, even for therapeutic uses, will start us on a slippery slope to using it for non-therapeutic and enhancement purposes, which many view as controversial.”⁵ Taking a line in favor of treatment versus enhancement, we have revealed the hazards of continuing to enhance societies’ differences using genetics, with the possibility of further differentiation among privileges. In this regard, we’ve discussed the difficulty of obtaining real equal access when genetic material is marketed as products instead of basic requirements. This scrutiny on trend trends in appearance customizability have raised ethical issues, i.e., illusory beauty ideals and the worrisome commercialization of persons. Although we have emphasized on a personal level of autonomy, broader socio-political and ethical concerns must be weighed against an individual’s right to decide. The chapter on effects upon human identity cautions against the elimination of difference through undesirable genetically changed individuals. We challenge the notion that genetic modification is a continuation of evolution, and raise doubts of success regarding progress while warning of the potential pitfalls. Finally, throughout this journey through the ethical fabric underlying genetic enhancements raises the question of strict ethical standards to be maintained during the indefatigable process of genetic perfection.

⁵ "What are the Ethical Concerns of Genome Editing?" National Human Genome Research Institute. Retrieved from www.genome.gov.

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Domestication-Induced Changes in the Morphology and Behavior of *Canis lupus*: A Comprehensive Exploration By Andrew Zheng

Abstract

As one of the earliest animals to form a partnership with humans, wolves (*Canis lupus*) have undergone remarkable evolutionary transformations and also made a big impact on human societies. The domestication of wolves has led to significant changes in various morphological and behavioral characteristics. This paper aims to comprehensively review the scholarly literature on wolves, covering historical contexts, phylogeny, genetics, and evolution, particularly focusing on the pressures of natural selection and selective breeding under human supervision. By synthesizing existing research, this paper seeks to provide insights into the effects of domestication, particularly on the morphology and behavior of *C. lupus*.

Keywords: *biology, genetics, selection, domestication, phylogeny*

History of Canine Domestication

Dogs have played a significant role in shaping human society since ancient times. At the beginning of the human-canine relationship, dogs would pull sleds for humans and aid in their hunts. As humans domesticated livestock, dogs would help with herding and game hunting. Culturally, dogs occupied a position of prominence—in ancient Egypt, they attained the status of deities. In modern times, dogs have fulfilled a variety of roles, including guard dogs, therapy dogs, rescue dogs, and more. Evolving alongside humanity, dogs have not only witnessed our shared history but actively shaped it, leaving a lasting impact on our lives, cultures, and emotions (Prassack et al., 2020).

Human domestication of animals began in Eurasia during the Pleistocene era, when our ancestors domesticated the gray wolf. Although it is clear that the domestic dog descended from the wolf, we do not know exactly when humans began to domesticate dogs. The first-ever inquiry into this question concluded that humans had domesticated dogs as far as 135,000 years ago (Vila et al., 1997). Other evidence, including archeological findings from the Belgian site of Goyet, indicates that dogs were first domesticated 36,000 years ago. However, skull fossils at the site suggest that the animals in question may have been wolves; the site's evidence is therefore insufficient to support any definitive conclusions regarding the timeframe for the domestication of dogs. The exploration of these questions has been attended by controversy: evolutionary biologist Greger Larson faults many previous studies for relying on the genes of modern dogs, claiming that "you can't solve this problem by using modern animals alone as windows to the past." Using a new technique called geometric morphometrics that can accurately evaluate the morphological features of canines, Larson and his team are investigating modern and ancient genes of wolves and dogs with a much greater degree of accuracy. They conclude that the domestication process occurred while humans were still hunter-gatherers, indicating that humans domesticated dogs between 12,000 and 32,000 years ago (Udell et al., 2010). Nevertheless, the evidence regarding when, where, and how domestication began continues to be unclear.

Still, a number of sites across the globe offer varying degrees of archaeological evidence that provide insights into the origins of this significant event. The site of Bonn-Oberkassel in Germany, for example, reveals the 15,000-year old remains of what appears to be a domesticated dog. The morphology as well as the genes are consistent with those of a dog (Parker et al., 2010). Additionally, the presence of a dog's burial next to that of a human signifies a tangible connection between the two species, further supporting the inference that the animals at the site may have been domesticated. Fossils obtained from other sites across Europe—in France, Italy, and Switzerland—are also genetically and morphologically consistent with the presence of domesticated canines, and, as such, support a similar time frame of domestication.

Geneticist Savolainen compared mtDNA sequences in a sample of 654 domestic dogs around the world. Using a molecular clock, he calculated an average domestication time period of 15,000 years ago, a finding that is consistent with the current archaeological evidence (Kapil & Yeary, 2011). In addition, studies on the Y chromosome haplotype tree find that dogs are in three major haplogroups (HG1-3/HG6 and HG23). The splits between the wolf and dog haplotypes within each haplogroup suggest a late Paleolithic origin of the domestic dog, a finding that is also consistent with previous data (O'Callaghan & Whatmore, 2011).

In summary, dog domestication reflects the enduring partnership between humans and canines. This relationship dates back from the ancient Pleistocene era to today, showing how humans and wolves have influenced each other over time. While the precise timeline remains a puzzle with missing pieces, the archaeological discoveries, genetic insights, and folklore weave a rich tapestry of our shared history.

Coevolution of Wolves and Humans

Wolves and humans most likely underwent a process of coevolution, a journey that was both mutually beneficial and profoundly transformative of both species (Pierotti & Fogg, 2017). In the early stages of this coevolutionary alliance, humans and wolves engaged in a reciprocal exchange of support. Humans, with their burgeoning agricultural societies, likely shared the spoils of their food with wolves, thus fostering a symbiotic relationship. Wolves, in turn, emerged as loyal companions and invaluable allies on human hunts. This interdependence laid the foundation for a transformation that fundamentally changed both species.

As wolves gradually came to rely on humans for sustenance and warmth, they were less subject to the rigors of the wild, a shift that may have led to the attenuation of certain characteristics that were essential to survival in the wilderness (Table 1). For instance, traits such as hyper-vigilance, territorial instincts, and the need for camouflage and stealth may have diminished over time. In the context of human-provided resources and protection, once-crucial attributes for thriving in the wild may well have become less important. The gradual decrease in aggression among domestic wolves exemplifies this transformative process, highlighting how cohabitation with humans influenced the very nature of these canines.

Table 1. Potential Attenuation of Characteristics in Wolves Due to Human Interaction

Characteristic	Description
Aggressiveness	In the wild, wolves need to be aggressive to defend their territory, hunt for food, and compete with other predators. As they became reliant on humans, the need for intense aggression may have diminished.
Independence	Wild wolves need to be independent hunters and survivors. As they formed bonds with humans, the necessity of independence might have lessened.
Hyper-vigilance	In the wild, wolves must be hyper-vigilant to detect potential threats and secure their survival. Relying on humans for protection may have led to a reduction in the need for constant alertness.
Territorial Instincts	Wolves in the wild fiercely defend their territories. With human-provided resources, the significance of territorial instincts may have diminished.
Camouflage and Stealth	In the wild, wolves use their natural colors and stealth for successful hunting. As they interacted with humans, these traits may have become less crucial.
Mating Behavior	In the wild, wolves may have specific criteria for mate selection based on natural factors such as fitness, health, and pack dynamics. Human influence, especially in captive or domesticated settings, might have led to changes in mate selection criteria, prioritizing traits that align with human preferences. Human-provided resources and controlled environments could also potentially have led to changes in the timing of mating seasons, as the availability of food and shelter no longer occurs strictly in tandem with natural cycles.

Note: These examples are speculative; the ways in which the characteristics are actually affected likely depend on various factors, including the nature of the human-wolf interaction and the specific environmental conditions in which particular wolves and humans are situated.

At the same time, humans found themselves dependent on wolves for companionship and protection. The selection process that humans initiated favored specific wolf traits, such as docility, obedience, and affection. Through generations of selective breeding, humans molded the once-wild wolves into domesticated creatures, giving rise to the diverse breeds of dogs we know today.

Pierotti and Fogg (2017) challenged conventional views in their book, *The First Domestication: How Wolves and Humans Coevolved*. Their book, which explores the wolf pack's close proximity to humans thousands of years ago, suggests a more cooperative coevolutionary

model. Humans and wolves, sharing resources and knowledge, coevolved together, fostering an alliance that transcended mere competition. Pierotti and Fogg's argument emphasizes the significance of cooperation in shaping ecological communities, providing a compelling framework to understand the benefits that humans gleaned from their alliance with wolves. This cooperative model, they contend, enabled humans to outcompete other hominids and expand into challenging environments, ultimately influencing the course of human history.

The evolution of dogs, which stemmed from this coevolutionary bond, reflects the changing needs of humans across different eras. From sled-pulling and protection in ancient times to herding during the agricultural revolution, dogs evolved in tandem with the demands that humans placed upon them. Modernity ushered in new roles for dogs as therapy and police companions, further shaping their evolutionary trajectory. The resulting diversity of dog breeds encompasses a mosaic of traits, preserving echoes of ancient roles while at the same time reflecting the roles they play today.

Canid Phylogeny

The evolution of *Canis lupus*, from its ancestral form to the diverse array of over three hundred modern dog breeds, is a complex and captivating process. The construction of a phylogenetic tree to trace this evolutionary history involves a comprehensive analysis that encompasses genetic, molecular, behavioral, and anatomical traits.

Central to phylogenetic prediction is the exploration of genetic markers. Microsatellite DNA polymorphisms and various mutations serve as indispensable tools, offering scientists the ability to make detailed predictions about the divergence of related species. Geneticist Parker, in a groundbreaking survey, analyzed the microsatellite DNA nucleotide sequences of wolves and 85 domestic dog breeds (Parker et al., 2010). This comprehensive analysis revealed a compelling division within the canine world—primitive dog breeds, including the Japanese Shiba/Akita, the Chow Chow, and the Siberian Husky, were distinct from their counterparts in the modern dog breeds, which predominantly comprise breeds of European provenance.

The integration of various traits, encompassing both behavioral and anatomical characteristics, serves as a valuable complement to the genetic foundation when constructing accurate phylogenetic trees (Fig 1). For example, Zoologists Zrzavý and Řičánková (2004) conducted separate and combined phylogenetic analyses, employing experimental cladistic approaches based on diverse data-partition combinations and taxon-removal analyses to inspect the phylogenetic dynamics of individual taxa. The preferred Canid phylogeny unfolds with the gray foxes (*Urocyon*) as the most basal canid, foxes (including true foxes, Fennec foxes, and Arctic foxes) forming a monophyletic group, and the doglike canids forming a clade that bifurcates into South American and Afro-Holarctic subclades. Notably within the combined tree, certain morphological traits related to development and behavior are notably abundant to contribute to the tree branching establishment. This holistic approach unravels the threads of evolution, providing a comprehensive perspective on the diverse paths that wolves went through to becoming domesticated dogs.

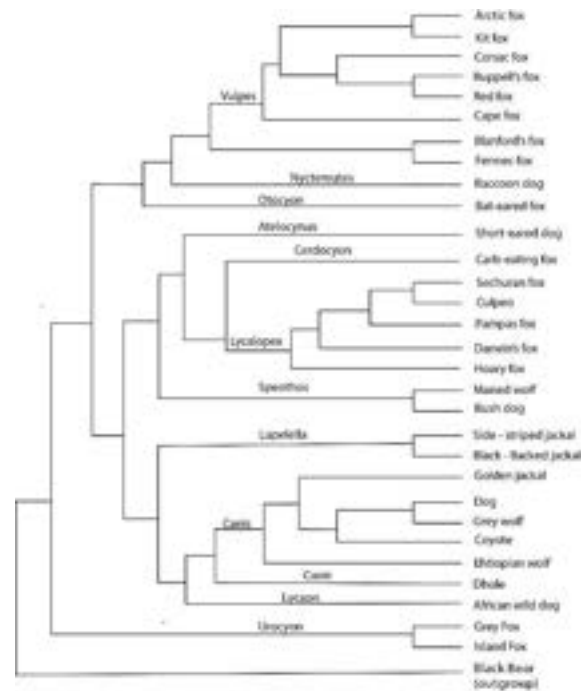


Fig 1. A general phylogenetic tree of canid species

In 2016, Zhang Ya-Ping's research group, in collaboration with researchers from China and Sweden, published groundbreaking research that involved whole-genome resequencing analysis of 58 canids, encompassing 12 gray wolves, 27 primitive dogs from Asia and Africa, and 19 modern dogs representing various breeds worldwide (Wang et al., 2016). The study revealed a significant finding—dogs originating from Southeast Asia exhibited higher genetic diversity compared to their counterparts. The population phylogenetic tree analysis positioned dogs in Southeast Asia as the fundamental group most closely related to gray wolves. Furthermore, site spectrum data analysis pinpointed the emergence of the earliest domesticated dogs in Southeast Asia to approximately 33,000 years ago.

According to researchers, around 15,000 years ago, domesticated dogs from Southeast Asia embarked on a global migration, proliferating throughout the Middle East, Africa, and Europe while collaborating with humans in hunting and herding activities. Subsequently, a cohort of dogs that had left Asia returned to the East, engaging in genetic exchanges with local breeds in northern China. Genetic comparisons between modern dogs and wolves suggest that humans might have domesticated wolves into dogs on multiple occasions. Following domestication, dogs from diverse origins interbred and occasionally reintegrated with wolves; they also exchanged genes with analogous species in the Americas, having crossed the then-unflooded Bering Strait. Ultimately, dog breeds originating from eastern Eurasia made a profoundly significant genetic contribution to modern breeds, surpassing the impact of breeds domesticated in western Eurasia.

Distinct environmental conditions, varied dietary habits, and the recurrent pairing of multiple breeds have given rise to the wide spectrum of canine characteristics we observe today. Phylogenetic trees, meticulously crafted through the synthesis of genetic, molecular, behavioral, and anatomical data, reveal the finely filigreed mosaic of the canid evolutionary lineage. From the primal roots of grey foxes to the branching diversity seen in modern dog breeds, the phylogeny stands as a testament to the adaptive prowess and enduring partnership between humans and wolves. This exploration into wolf and dog phylogeny enriches our understanding of canine evolution and underscores the remarkable journey that has led to the myriad forms, functions, traits, and abilities of our beloved canine companions.

Genome Evolution

The dog's genome consists of 78 chromosomes, which, for the most of their evolutionary history, has remained relatively stable (Wayne et al., 1999). This means that there were no abrupt changes in the number of chromosomes they possess. However, dogs over the course of their evolution have nevertheless acquired more than 2 million single-nucleotide polymorphisms (Lindblad-Toh et al., 2005). The first domestic dog genome was sequenced in 2003, with a 1.5-fold sequence redundancy. Researchers determined that the entire dog genome was 2.41 Gb long, and they identified nearly 20,000 protein-coding genes. The dog genome consists of approximately 2.5 billion DNA base pairs, which is less than that of other mammals. Mammals such as the mouse, a commonly studied mammalian species, have a genome of 2.7 billion base pairs (Waterston et al., 2002). In comparison, humans have a larger genome size of 3 billion base pairs (Venter et al., 2001).

A number of studies of dogs' mtDNA—DNA in the mitochondria that have uniparental inheritance—showed that there was no significant difference in mutation rate between wolves and dogs. However, ML (Maximum-Likelihood), an estimate of the ratio of the nonsynonymous and synonymous substitution rate, was significantly lower in the branches that separated wolves and coyotes (Savolainen et al., 2002). Researchers hypothesize that there are many deleterious mutations within the wolf population. When researchers compared the ML ratio of dogs to that of wolves, they found that the dogs' ratio was significantly higher. This, in turn, suggested that dogs accumulate an abundance of deleterious mutations within their mtDNA due to the relaxation of selective pressure. Because humans have taken over the selection of dogs, dogs' lifestyle and selection were not based on the process of natural selection, a fact which lowered the selective pressure upon them. This leads to dogs possessing greater nonsynonymous mutations in their mtDNA, a fact that, over a long-enough period of time, would significantly affect their genome. This ML ratio also potentially explains the vast phenotypic diversity that is present in dogs as well as the increasing number of fatal diseases affecting dogs worldwide (Savolainen et al., 2002).

One of the very first genetic studies that sought to understand canine morphology was conducted at the University of Utah by biologists Karl Lark and Kevin Chase. They specifically studied the Portuguese Water Dog, an ideal breed for this type of study as it derives from only a small number of founders (Chase et al., 2002). The project led to the development of principal

components, sets of correlated traits that defined the morphology of the Portuguese Water Dog. An intriguing part of Lark and Chase's investigation was a locus on the canine's chromosome 15 (CFA15) that demonstrated a strong correlation to body size. They searched for SNPS in a roughly 15 million base pair region and genotyped the resulting sequence on all Portuguese Water Dogs. The resulting gene was IGF1, which is also known to influence body size in other mammals. After extrapolating that particular study so as to apply to many other dog breeds, much of the evidence pointed toward the idea that IGF1 was responsible for larger or smaller dog sizes. Thus, breeders are likely placing a selective pressure upon the IGF1 gene when they seek to create smaller dogs. This type of selection results in the huge variability in size that modern dogs possess.

Further research on genetics and body size shows that integral genes underlie much of the body size variation. For example, the six genes (GHR, HMGA2, IGF1R, IGF1, STC2, SMAD2) explain about half of the variation in body size for dogs with a standard body weight under 41 kg. Above 41 kg, studies of the X chromosome show that three genes (ACSL4, IGSF1, and IRS4) are just as responsible for the heavier dog breeds.

Genetics also plays a crucial role in determining the variation in skull shape, another morphological trait that is highly diverse in dogs. A comprehensive analysis involving over 300 dogs has identified the gene SMOC2 as a key player (Jones et al., 2018). SMOC2 is a member of the matricellular protein family BM-40 (SPARC), characterized by its possession of an extracellular calcium-binding module and a follistatin-like domain (Smith et al., 2017). Notably, this single gene accounts for approximately 36% of the variation observed in skull shape among dogs. This finding provides valuable insights into the molecular mechanisms underlying the diverse skull morphologies observed in different canine breeds, shedding light on the genetic basis of this phenotypic diversity.

Dogs also exhibit highly diverse coats, which can be explained by the three genes (RSPO2, FGF5, and KRT71). These genes are critical to determining the coat length of dogs. Variations in various genes that affect the coats of dogs, such as the transcription factor family (FOX13) that cause hairless dogs, explain much of the coat diversity. The genes AGSIP, MC1R, and CBD103 encode the ligand-receptor system that controls pigmentation in dogs. This adds an additional layer of complexity to the genetics that determine the variation among dogs.

Overall, genomic research has pinpointed a set of genes that experienced positive selection during domestication. Mutations within the dog genome, along with the distinct artificial selection pressures imposed on them, have been instrumental in driving the evolutionary trajectory of dogs, leading to their increasing genetic and phenotypic distinctiveness compared to their ancestors (Plassais et al., 2019).

Decoding Canine Diversity

Since Darwin's era, dogs have stood out as land mammals with unparalleled morphological diversity. Exhibiting extreme forms of variation, dogs boast a vast array of breeds, with the American Kennel Club (AKC) recognizing 200 breeds in the United States alone and

more than 400 breeds worldwide. While the mechanisms that govern this remarkable diversity warrant further exploration, three key sources of genetic variation emerge as potential contributors.

Fonder and Gardener shed light on the role of microsatellites, or simple sequence repeats, in driving genetic variation among dogs. Notably, microsatellites occur at a rate 100,000 times greater than that of single nucleotide polymorphisms (SNPs), a fact which accentuates their significance (Fonder & Gardener, 2017). The Canidae family exhibits elevated genome-wide slipping rates, a phenomenon where DNA replication errors create new alleles in repeating elements. The unique genomes of dogs are composed of approximately 31% repeating sequences—chief among them, carnivore-specific short interspersed nuclear elements (SINEs), such as SINEC_CF. The low divergence and abundance of these SINEs underscore the extraordinary genetic diversity of canines.

The intensification of artificial selection, particularly during the Victorian era, has played a pivotal role in shaping the diversity observed in modern dogs (Smith, 2008). The selective breeding practices employed over centuries have amplified the range of morphological traits, creating a diverse spectrum of breeds. The delicate interplay between genetic variation, artificial selection, and historical breeding practice has produced the rich tapestry of dog breeds seen today.

Two major drivers underscore the evolution of dogs: diet and environment (Jones et al., 2018). In contrast to their lupine counterparts, dogs have adapted to a diet rich in starch and carbohydrates. Genes like *AMY2B*, *MGAM*, and *SGLT1* play a significant role in facilitating this dietary shift, aligning with the theory of domestication-induced changes in diet. Environmental adaptation emerges as another key driver, exemplified by breeds like the Tibetan Mastiff, which evolved characteristics that enabled them to thrive in high-altitude environments. Genomic sequencing reveals variants like G305S that aid in oxygen transport, showcasing the profound influence of the environment on canine evolution.

Further insights into the drivers of dog evolution emerge from dogs' ability to adapt to specific challenges. The African wild dog's adaptation to malaria, a consequence of their migration to Africa around 15,000 years ago, reveals the role of genes like *ADGRE1* in providing resistance (Brown et al., 2020). These examples provide a nuanced understanding of the complex forces that have influenced the evolution of dogs over time.

Domestication Dilemma: Wolves vs. Foxes

Human success in domesticating wolves stands in stark contrast to the challenges humans have encountered in attempting to domesticate other wolf-like animals, notably foxes. The Canidae family, to which both wolves and foxes belong, shares common features, yet the domestication narrative within this family takes divergent paths due to the delicate interplay of social and physical dynamics. Table 2 provides a concise comparison of key social, behavioral, and physical attributes of wolves and foxes.

Table 2. Comparison between Wolves and Foxes: Social, Behavioral, and Physical Attributes

Aspect	Wolves	Foxes
Social Nature	Highly social, living in packs.	Solitary animals, preferring to be alone
Leadership Dynamics	Follow a strict hierarchical structure with an alpha leader	Lack a clear pack structure
Physical Attributes	Larger and stronger than foxes, advantageous in cooperative endeavors	Smaller and less physically imposing
Hunting Strategy	Hunt in packs, employing collaborative tactics	Prefer solitary hunting, lack pack dynamics
Domestication Suitability	Social adaptability and physical strength make them ideal partners for humans	Solitary nature and smaller size make them less amenable to domestication compared to wolves

Wolves exhibit a highly social nature, forming cohesive groups known as packs (Mech, 1999). Within the pack, a strict hierarchical structure prevails, with an alpha assuming a leadership role. Crucially, when humans engage with wolves, they seamlessly occupy the alpha position, a position that wolves are genetically programmed to respect and follow (Cassidy et al., 2017). This natural affinity for hierarchy makes wolves amenable to human leadership, facilitating the process of domestication. The profound social cohesion among wolves aligns with human societal structures, creating an environment conducive to cooperation.

In contrast, foxes emerge as solitary creatures, displaying a marked deviation from the social tendencies of wolves (Macdonald & Reynolds, 2004). Preferring solitude in both life and hunting, populations of foxes are marked by a social dynamic that is incompatible with the cooperative nature of wolf packs. Attempts to integrate such solitary behavior into human culture have proved to be challenging, as the independence of foxes is at odds with the collaborative instincts of domesticated animals.

The physical attributes of wolves also play a pivotal role in the amenability of wolves to domestication vis a vis foxes. Wolves, larger and stronger than foxes, possess a natural advantage in human-animal partnerships (Coppinger & Schneider, 1995). Their size, combined with the pack hunting strategy, positions them higher on the food chain. From a human perspective, it is logical to ally with animals that bring both physical prowess and social cohesion. This inherent advantage positions wolves as preferred companions, reinforcing their suitability for domestication.

Wolves, with their dual advantages of social adaptability and physical prowess, emerge as ideal candidates for human partnership (Morey, 1994). The convergence of social dynamics that align with human structures and the physical strength inherent in wolves sets the stage for a

successful domestication narrative. In contrast, the solitary disposition and comparatively diminished physical stature of foxes render them less amenable to the cooperation with humans (Macdonald & Reynolds, 2004).

Domestication-Induced Changes in the Morphology and Behavior

Over time, dogs have evolved distinct features that separate them from their lupine ancestors; however, they still maintain a degree of resemblance. Dogs, in particular, embody paedomorphism, a characteristic in which adult animals retain juvenile features (Hare & Tomasello, 2005). At first glance, dogs seem quite closely to resemble wolves—after all, dogs are direct ancestors of wolves. However, dogs are noticeably smaller. Many theories suggest that over time, the domestic dog became smaller because smaller wolves are more manageable (Savolainen et al., 2002). Logically, this makes sense, because smaller wolves were easier to tame than larger wolves. Moreover, scientists believe that when humans partnered with wolves, wolves had to adapt from eating only meat to eating a combination of meat and vegetables. This also explains how modern dogs are able to handle starch (Axelsson et al., 2013). Wolves also fed more on the scraps from human foods. This selective pressure favored the smaller wolves that needed less food. Finally, wolves reach sexual maturity at around two years old—much later than dogs, who reach sexual maturity between six and 12 months (Trut, 1999). Indeed, biologist J.P. Scott even notes that canine domestication “may be regarded as ecological colonization of a new niche” that would support paedomorphism in the descendant species. Over time, humans increasingly favored paedomorphic traits (large eyes, small body, large forehead, etc). Scientists have dubbed this phenomenon—the alteration of the morphology, physiology, and behavior of an animal via domestication—“domestication syndrome.”

One of the most famous instances of domestication syndrome was Belyaev’s experiments on silver foxes (*Vulpes vulpes*) (Wilkins et al., 2014). Belyaev hypothesized that the driving force behind the domestication of animals was their tameness. Belyaev noticed that by selecting the silver foxes on the basis solely of tameness, other traits such as floppy ears and colored pigmentation began to occur about ten generations later (Trut, 1999). Obviously, this selection of tameness greatly decreased the foxes’ aggression and increased their sociability and playfulness. The foxes’ retention of playfulness also hinted at paedomorphism. Based on Belyaev’s study of silver foxes, a number of scientists concluded that many of traits associated with morphological domestication syndrome were highly correlated to an animal’s tameness, and thus were seen as a product of tameness.

Behaviorally, dogs became increasingly docile and submissive towards humans. Research has also shown that the act of dogs and humans gazing at each other leads to an oxytocin feedback loop, analogous to that which exists between an infant and its mother (Nagasawa et al., 2015). This feedback loop, however, is not found between wolves and humans, suggesting that certain selective processes caused significant behavioral and hormonal evolution in dogs (Hernádi et al., 2015). This oxytocin feedback loop is crucial to maternal-infant relations. As this feedback loop became stronger, so did the bond between humans and dogs. Evolutionary

theorists suggest that certain common environments selected for traits that allowed a degree of eye contact between dogs and humans, which led to the oxytocin feedback loop. This is an example how many different factors—genetics and morphology—can influence the behavioral evolution of dogs.

Because humans naturally favor paedomorphic characteristics in wolves, the wolves that were domesticated gradually became smaller. A specific type of muscle movement around the eyes (termed the AU101 eyebrow raise) was particularly selected for. Recent studies also show that facial musculature between the wolf and dog are relatively similar, except around the eye (Hare et al., 2002). Dogs have ‘extra’ muscles around the eye that make them appear more infant-like. This type of muscle movement in the dogs' eyes made their eyes look bigger and more paedomorphic, a fact which, perhaps, elicited a caregiving response from humans, similar to that which a parent shows to an infant.

Another reason for which this type of muscle movement around the eyes was selected is communication. Humans rely not only on verbal communication but also on facial expression and body language. Wolves did not have the same ability to raise their eyebrows, while the domestic dog did. Humans, consciously or unconsciously, selected for more paedomorphic characteristics that were presumably more beneficial, resulting in a type of selection for those characteristics. Overall, researchers found that wolves that produced this AU101 eyebrow raise were more likely to be partnered with humans, which helped those wolves to enjoy greater reproductive success (Hare et al., 2005).

Morphologically, the domestic dog had more variation than wolves in regard to their cranial measurements. These measurements are widely used as sure indicators of differences between the two species. Of especial importance are the broadening of the braincase, skull size reduction, the shortening and widening of the snout, and the reduction of dentition. These changes, especially the shortening of the skull, are also prevalent in many other domesticated mammals, such as pigs (Wilkins et al., 2014). In a comparison of the carnassial teeth length between dogs and wolves, no significant differences were found (Larson et al., 2012). This is to be expected, because the evolutionary changes in teeth were found to have occurred significantly more slowly than changes in the skull.

Conclusions

The historical context of the human-dog relationship is invaluable in comprehending the evolutionary processes that have transformed dogs during domestication. The inclusion of phylogenetic analyses further enriches our understanding by unraveling the systematic relationships among dogs, and the interconnectedness of various dog breeds and their shared evolutionary trajectories. This phylogenetic perspective is essential in deciphering the underlying patterns that shape the morphological and behavioral diversity within the extensive canine population.

Genetic and genomic studies, which focus on the unique features embedded in the dog genome, further enhance our understanding of the morphological variations and diversity across

dog breeds. The interplay of genes provides geneticists with a roadmap to elucidate the mechanisms driving the observed morphological changes. Moreover, the phenomenon of artificial selection, guided by human preferences and needs, acts as a powerful force behind the diversity present in dog breeds. The mechanisms underlying this variation further illuminate the dynamic processes that influence both the morphology and behavior of dogs.

In addition, specific findings and feedback loops in the history of dogs establish a compelling connection between morphology and behavior. It is evident as changes in behavior often emerge as by-products of domestication and the selective pressures that act on morphology. Notable experiments, such as Belyaev's work with silver foxes, exemplify how alterations in behavior are intertwined with the morphological shifts occasioned by domestication and selective breeding.

In essence, the prevailing trend arising from the process of dog domestication is that of paedomorphism. This trend, which is characterized by the retention of juvenile traits into adulthood, underscores the impact of domestication as it shapes both the morphological features and the behavioral traits of dogs.

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Cultural Gourmet: Exploring the factors of multicultural menu selections in the restaurant industry in the US By Kyle Chen

Abstract

This study analyzes the complex interactions with ethnically diverse factors that shape menu choices within multicultural restaurants in tourist destinations of the United States. Focused on understanding customer preferences and to improve the satisfaction for menu selection, the research emphasizes that such a sophisticated awareness of these elements is absolutely necessary for the task aimed at personalizing their products and offering an overall better dining experience. Using both qualitative and quantitative methodologies such as interviews, surveys, combined with existing insights from the literature, the study thoroughly explores the unique landscape of multicultural restaurants. It concludes that many factors such as location, authenticity, reviews, ambience play a crucial role in shaping customer preferences and satisfaction. Together these different elements form the unique set of factors that contribute to the nuanced decision-making process of customers when selecting dining options.

Introduction

In the world of multicultural restaurants in tourist destinations, a puzzle emerges for both diners and restaurant owners, learning the complex network of cultural diversity in menu selection. Multicultural restaurants refers to dining places that offer a wide range of cuisines which are inspired by various cultures and ethnicities. These restaurants have to face an obstacle of how their menu items correspond with the many preferences coming from different cultures. As more people travel to these locations, the more difficult it becomes to determine what standards value for money in an environment where consumers may have widely differing expectations for food quality. In this study, hidden factors were discovered that shaped how customers perceive and enjoy their dining experience, especially with diverse food options influenced by tourism. Exploring the factors driving cultural diversity in menus of ethnically diverse restaurants within tourist destinations, this study delves into their impact on customer satisfaction. Understanding customers' decision-making processes and the multifaceted nature of the dining experience, we hope to provide valuable information for businesses seeking ways of leveling up their menus.

This study will focus on the factors behind cultural diversity in menu selection to improve customer satisfaction for restaurants in multicultural destinations. Analyzing the complex network helps understand how various preferences influence customer satisfaction. Uncovering these trends, companies can align their menu options to address a variety of customers coming from different groups. Beyond restaurants, the study contributes to cultural dynamics in the hospitality industry. The results will have a significant value for business by highlighting the traits with culturally different expectations, suggesting a more diverse and satisfying dining experience. With the rise of multicultural tourist destinations, this study offers

useful information for businesses working in the highly diverse market, changing these industries' processes towards a custom satisfaction approach.

Methodology

Surveys serve as the chosen methodology for this study, as they are relevant to determining what causes cultural diversity. Quantitative results on customer satisfaction and preference will be easily derived from different opinions on the surveys. The author presents a QR code to scan for the survey in the specific dining place. Besides the survey, the study will offer a mixed approach involving literature review and content analysis to provide a variety of comprehension that makes it convenient for customers to express themselves. Starting off with a literature review to create a theoretical framework through findings on cultural influence in the menu selection. This step establishes the target variables and creates a foundation for this study.

Surveys were distributed to customers after their meals, allowing them to share feedback on how the cultural influences are reflected in the menu. This convenient approach involves scanning a QR code provided to them. With surveys, content analysis brings the possibility for both quantitative and qualitative research together which provides very important detailed information about the customers satisfaction and preferences. Analysis will be used to analyze the qualitative results of customers responses that were recorded through the survey. In this stage, the analysis will involve examining the responses recorded from the survey, looking for patterns and themes that were repetitive and related to cultural influences.

Additionally, interviews will take place with restaurant owners or managers to gain a deeper understanding of how cultural diversity influences menu selections from the business owners perspective. Utilizing qualitative information will add more context in the researching findings overall. In conclusion, this mixed approach will not only strengthen the researchers credibility but also adds a layer of perspective to support the businesses. This approach enables us to gain further knowledge of how cultural variations impact on people's choices within the rapidly growing hospitality and tourism industry.

Literature Review

As the number of travelers increases it is critical for restaurants to understand the factors that shape their menu preferences. Focus of this study will be on strategies for businesses to enhance the dining experience for a varied ethnicity of tourists. Recognizing the significance of this study is apparent when we realize that studies discuss the effects of culture on food preferences, but do not mention a very specific setting which is tourist destinations. This study seeks to address that gap, underlining the close examination of the factors that influence menu choices in these tourist destinations. In the academic world, by employing both qualitative and quantitative methods, including surveys for a comprehensive understanding. With this dual approach we become better informed on cultural diversity to food preferences in multiethnic settings located together within tourist places. The study's methodology, particularly the survey, not only improves the understanding of this particular context but also provides new and

valuable insights to academic conversations on the impact of cultural factors such as those which are revealed through the survey's responses.

Table 1: Literature Review

Study	Research/ Objective Question	Method	Country/ Market	Factors/ Dimensions / Variables	Findings
1.Liu and Mattila (2015)	How the impact of the absence of authentic menus in ethnic restaurants affect customer satisfaction	Quantitative	USA	1. Authentic menu presence (Offered vs not Offered) 2.Ethnic Composition of other customers (Asian vs White)	1. American customers show less satisfaction when ethnic restaurants do not offer an authentic menu. 2. The race of consumers like Asian or Caucasian changes the customer satisfaction, making them feel more a part of the ethnic group or unique.
2. Kim and Baker (2017)	How do menu elements and staff appearance influence customer views of authenticity in a ethnic restaurant?	Quantitative	Global	1. Menu element affects authenticity 2.Employee ethnicity/name affects authenticity	1. Impact of menu elements such as names,descriptions impact perception of authenticity in food, culture, and employees 2. Race,name of servers influence perceptions of authenticity 3. Food and cultural authenticity increases revisit intentions and willingness to pay more
3.Feng, and Fox (2018)	How do socio-economic and race ethnic factors influence the usage and impact of	Quantitative	Global	1.Ethnicity 2.Socio-economic status	1. Blacks and Hispanics used labels more in restaurants 2. More educated individual have the tendency to use labels more

	menu calories labels over time?				
4.Kim et al.	How does the authenticity impact customers emotions and behavioral intentions in Chinese restaurants in the US	Quantitative	USA	<ol style="list-style-type: none"> 1.Decoration/Furnishing in restaurant 2. Music 3.Menu presentation 	<ol style="list-style-type: none"> 1.Menu and furnishing contribute to positive emotions 2.Menu presentation and music significantly influence negative emotions 3.Positive and negative emotions are connected between the authentic environment
5. Lu et al.	How does the consumer's view of authenticity impact the brand's equity and choice intention in ethnic restaurants?	Quantitative	USA	<ol style="list-style-type: none"> 1.Brand awareness 2.Brand association 3. Authenticity perceptions 4.Brand Loyalty 	<ol style="list-style-type: none"> 1. Authenticity perception positively influence brand awareness, association and loyalty 2. Brand awareness positively influences association and loyalty 3. Brand loyalty is influenced by authenticity perception,association, and awareness
6.Liu and Jang (2009)	What characteristics of Chinese restaurants affect the satisfaction and future intentions of Americans?	Quantitative	USA	<ol style="list-style-type: none"> 1. Food taste 2.Service 3.Cleanliness 	<ol style="list-style-type: none"> 1. Food taste, service, and cleanliness are crucial factors as they influence customers satisfaction and future intentions 2. Particularly food taste plays a key role in shaping customers overall experience 3. The IPA highlights the need for cleanliness for improvement in Chinese restaurants

7.Jia (2020)	Do Chinese and US tourists differ in restaurant experiences based on reviews, considering cultural influences.	Quantitative	China and US	1.Ratings 2.Food appeal	1.Positive customers ratings correlating with overall satisfaction 2. Culinary appeal significantly influences positive reviews 3. Customer perception shapes satisfaction and reviews in the restaurant industry
8.Sattaezadeh et al.	Do Persian restaurants in London perceive authenticity and utilize strategies/sensory elements in their business?	Qualitative	UK	1.Awareness of ethnic restaurant owners 2.Sensory elements in restaurant	1. Ethnic restaurant owners showed limited awareness of authenticity, showing a gap of understanding of customer expectations 2.Our senses like hearing,smelling, and tasting influence how we experience dining and customer perceptions
9.Aybek, and Ozdemir 2022	How do ethnic restaurants experiences impact future tourism	Quantitative	Turkey	1.Ethnic restaurant experience 2.Tourist intentions 3.Food image perceptions	1. Ethnic restaurant experience positive influences locals intention to eat authentic cuisines 2. Ethnic restaurant experiences has a positive impact on shaping tourists perceptions of destination food, and future visit intentions
10. Meng and Choi (2017)	How does the theme of a restaurant experience, including authenticity impact customers	Quantitative	USA	1. Physical environment 2.Satisfaction 3.Perceived authenticity 4.Overall quality of	1. The physical environment of themed restaurants significantly influence customer satisfaction 2. Customer satisfaction is important to shape perceived authenticity within the restaurant 3. Perceived authenticity has a

	quality of life			life	<p>moderate relationship between customer satisfaction and overall quality of life</p> <p>4. The overall quality of life of themed restaurant customers is positively impacted by their satisfaction and perceived authenticity.</p>
11. Liu and Li (2018)	How does perceived authenticity influence behavioral intentions in an independent mainstream ethnic restaurant	Quantitative	USA	<p>1. Perceived authenticity</p> <p>2. Cultural Familiarity</p> <p>3. Cultural Motivation</p>	<p>1. Perceived authenticity shapes customers' quality opinion of the restaurant, the most important role in any factor.</p> <p>2. Customers with higher familiarity and interest in Italian culture attach greater value to restaurant authenticity</p> <p>3. Customers with higher cultural motivation, tend to place greater value on perceived authenticity of the restaurant</p>

Through the literature review it reveals several themes in the realm of restaurant dynamics. Firstly, authenticity emerges as crucial factors that influence customers' experiences and satisfaction (Liu & Mattila, 2015, and Kim & Baker, 2017). The presence of authentic menus, staff appearance and menu elements in the formation of the customer's perception is very important. Furthermore, cultural impacts on menu items are further considered. Feng and Fox (2018) explored how income and race affect the usage of menu calorie labels, clarifying the intricacy of the relations between socio-economic variables and dietary decisions. Simultaneously, Jia (2020) explains the wide range of the restaurant experiences of Chinese and US travelers, which provide the much needed insights into this complex interplay of cultures in the dining sphere.

A broader theme unraveled the impact of restaurant experience on overall customer satisfaction and quality of life. Meng and Choi (2017) paper highlights the importance of the physical environment and thematic consistency in the provision of quality of life and customer satisfaction. These key elements combine to offer a comprehensive and varied perspective of what influences a customer's encounter at a multicultural restaurant.

Survey

Menus in the multicultural restaurants for tourist destinations were studied through the survey and also interview process to understand what determines cultural diversity in menu

selection. The period of data collection will be a course of two months during the normal working hours. To get the best feedback, the focus was placed on those customers who had just finished dining. Additionally, the interviews were held with the two owners of multicultural restaurants.

The survey was created with the intention to be both very convenient and also practical, having a QR code for the customers who would scan it after eating. This approach guaranteed a seamless and also prompt capturing of insights while the customers dining experience were still fresh on their minds. The survey contained both closed and open ended questions that addressed different issues including the authenticity of restaurants, causes for menu preference, satisfaction levels at the cultural diversity in menus, and what they look for in a multicultural restaurant.

Survey Form Table

<p>Hi, this survey is for research purposes to better understand and improve dining experience at restaurants. Your answers will provide information that will support our research into the factors that influence menu choices that reflect ethnic diversity. Please take a moment to provide your honest responses, that are very important.</p> <p>https://forms.gle/WY2b4LTfRZfjuJxQ8</p>		
Questions	Response Choices	%age
Q1. How often do you dine at multicultural restaurants?	Rarely (Once or twice a month) Sometimes (Two to four) Often (Four or more)	13.9% 51.4% 34.7%
Q3. Are you from around here, or are you a tourist	Ann Arbor Different city Different State International	48.0% 42% 9.0% 1.0%
Q4. What factors influence your decision to try a new multicultural restaurant?	Reviews/ Recommendation Location Advertisement Multi-Cultural food diversity Price and value Ambience and decoration Authentic flavors Presentation of food Staff knowledge Nutritional values	15.02 14.08 8.13 9.51 9.89 6.54 11.31 8.81 1.83

Q5. Which cultural cuisines do you enjoy most when dining out?	Chinese Japanese Italian Indian Mediterranean American Mexican Middle Eastern French	16.76% 17.80% 11.18% 7.10% 5.58% 7.63% 15.81% 3.05% 1.52%
Q6. How satisfied were you with the multi-cultural diversity of food menu options for your dining experience today?	Dissatisfied Somewhat satisfied Satisfied Very satisfied	4.00% 23.8% 47.5% 24.8%
Q7. How important is authenticity in cultural dishes in restaurants?	Not important Somewhat important Very important	2.9% 71.6% 25.5%
Q8. How accurately do you think the cultural dishes here served represent the culinary traditions of their cultures?	Not accurate Somewhat Accurate Very	9.7% 45.6% 39.8% 4.9%
Q9. How likely are you to return to a restaurant that incorporates authentic cultural elements into its menu?	Not likely Likely	21.8% 78.2%
Q10. What's your preferred method of making a reservation?	Walk-in Online Phone call Mobile app No preference	19.4% 42.7% 25.2% 7.8% 4.9%
Q11. What's your age group?	Under 18 18-25 25-34 34-45 45-54 55-64 65+	5.9% 33.3% 25.5% 14.7% 13.7% 13.7% 1.0%

Q12. What's your Ethnicity	Asian Caucasian Black/African Hispanic Others	33.0% 50.5% 10.7% 5.8% 0.00%
Q13. What's your Gender?	Male Female Others	58.4% 40.6% 1.00%

Survey results provide insights about the dining preferences of multicultural restaurants across the United States. By analyzing the customers behaviors, preferences, and demographics, the research examines the factors shaping customer choices and satisfaction. These results offer guidance for current restaurant owners, uncovering specific trends and patterns in the survey.

The survey results showed several ideas about the dining habits of those who participated in the survey. A notable finding is the frequency of visits to restaurants that feature multicultural menus. Furthermore, the results from the survey showed that 34.7% of respondents described eating out more than four times a month, this shows the necessity to understand this target audience. The diverse representation in the survey, ranging from various age groups, ethnicities, and genders, makes the study more in-depth in the analysis. This highlights the varied perspectives and preferences within the customer base, emphasizing the importance of restaurants offering to cater the customers preferences.

Through careful data analysis, location emerged as one of the most important factors in the selection of restaurants, with 20.97% participants indicating that it was important to them. It highlights the different viewpoints and preferences within the consumer base, stressing the role of accommodation in the restaurant's offerings. Also the influence of reviews and recommendations were significant factors of selection, as indicated with 22.33% of the individuals surveyed. Word of mouth served as an important factor in determining customer choices, showing how positive reviews can attract more people within multicultural restaurants. Restaurants should actively encourage satisfied customers to share their experience with others or online to create a positive presence.

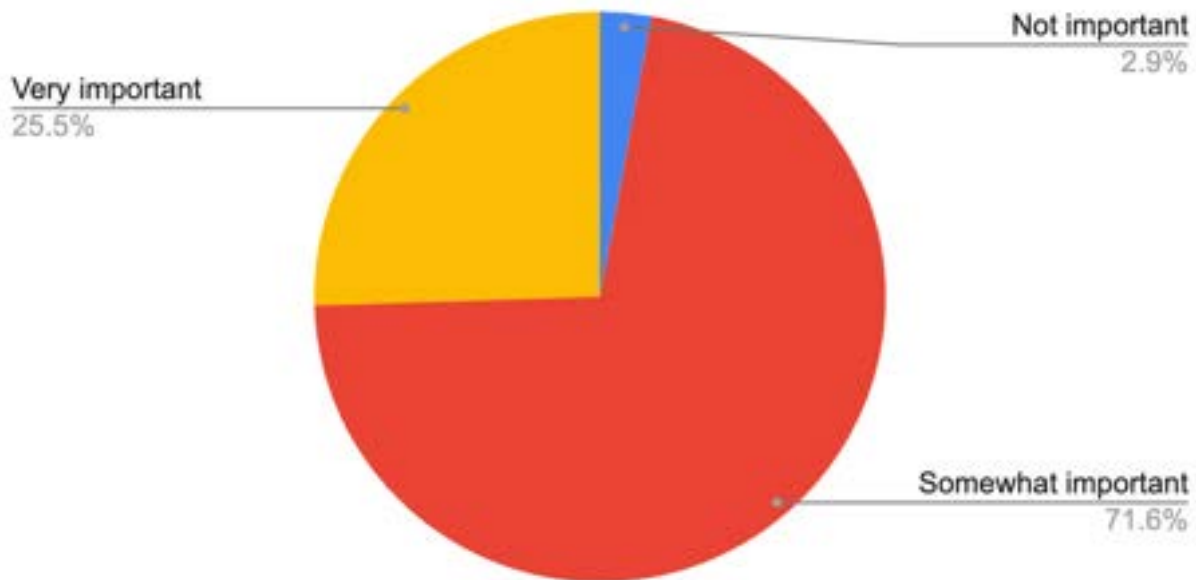


The respondents' cultural cuisines preferences were varied, with Japanese (17.80%) Chinese (16.76%), Mexican (15.81%) and Italian (11.8%) being the most popular choices. Satisfaction levels regarding the diversity of food options were high, with 47.5% being satisfied, and 23.8% somewhat satisfied.

Authenticity is a great importance for 71.6% of respondents that considered it somewhat important. However, 25.5% firmly believed that it is very important to emphasize a substantial portion of the customer base that values authentic cultural dishes. Nevertheless, 78.2% of the

people surveyed showed a willingness to return back to a restaurant that served authentic elements.

Importance of Authenticity in Cultural Dishes



The survey also asked about the preferred reservation method with 42.7% participants preferring online reservations, 25.2% respondents opting for phone calls, 19.4% choosing to walk in and 7.8% users favoring mobile apps. This diverse distribution emphasizes the wide range of ways customers make a reservation, which creates the opportunity for restaurants to enhance their reservation systems. Online reservations become the most common method, showing us that there is more reliance on digital platforms for convenience and efficiency in the dining experience.

Interview

Through a qualitative analysis, interviews with stakeholders were conducted, in order to gain a deeper understanding of the dynamics of multicultural menu choices in the restaurant industry. This interview plays an additional role to the quantitative data in the research, giving a qualitative layer into the experiences, perceptions and strategies of those directly involved in the multicultural dining field. Through interviews with restaurant owners, and chefs, we discovered the complex details that go beyond statistical values, we get a closer look at the real world issues and decision making processes that create the unique multicultural culinary offerings in the United States.

There were interviews conducted with the two owners of multicultural restaurants, which are very diverse in food. The study selection aimed to understand various opinions of the stakeholders in the industry due to its multicultural nature. For customers, the primary focus is on the questions asked where to understand their dining preferences, the influences of cultural

diversity on the menu choices, and their overall satisfaction with the restaurant. These questions were all constructed to view the dynamics of shaping the customers choices.

In order to conduct insightful interviews with the two restaurant owners carefully selected for their culinary diversity in establishments. These owners offered valuable insights into how to overcome the difficulties and take advantage of the opportunities regarding cultural diversity in menu selection. The first owner of a multicultural restaurant with a focus on Japanese cuisines, expressed how to carefully craft a menu reflecting the authenticity of the menu that shows off different cultures. He talked about small ingredients such as garlic butter being chosen to enrich the flavor of the Hibachi, adding a more diverse ingredient. The second owner, who ran a Taiwanese noodle shop that also served Japanese dishes such as sushi, focused on innovative techniques to combine the cultural elements in the menu. These interviews, carried out through ethical practices, helped to better understand the role that cultural diversity plays in the building of multicultural restaurants within touristic destinations.

Interview table

Questions	Verbatims	Dimensions
<p>Q1: How do you elaborate on your philosophy behind creating a culturally inclusive menu? What motivates you to incorporate these diverse cultural elements?</p>	<p><i>“Our philosophy centers around blending the different flavors of Taiwanese ramen, with a blend of Japanese cuisines. I am driven by the passion for a unique fusion experience, incorporating both Sushi and oru signature Taiwanese ramen.”</i> (P1, Ramen shop, Male)</p> <p><i>“Our motivation lies in catering diverse tastes to our customers. It's all about creating an inclusive space where customers can enjoy the comforting familiarity of Taiwanese ramen while also exploring new similar flavors.”</i> (P2, Ramen shop, Male)</p> <p><i>“I believe in a diverse community where everyone feels comfortable and belongs. My desire comes from building a space that welcomes and</i></p>	<ul style="list-style-type: none"> -Culinary fusion- Blending Taiwanese and Japanese Cuisine -Cater diverse taste -Inclusive space -Creative twists (Fusing Japanese techniques with creative twists, Tempura Cheesecake.”

	<p><i>resonates with everyone.”</i> <i>(P2, Japanese steakhouse, Male)</i></p> <p><i>“We like to fuse traditional Japanese steakhouse techniques with creative twists, offering an inclusive and unique dining experience. One of our recent items, Tempura Cheesecake, was a dish that was influenced by cultural diversity, blending the Japanese tempura flavor with a familiar taste of American cheesecake. This dish has becoming a customer favorite, capturing our customers love for both American and Japanese culinary delights”</i> <i>(P2, Japanese steakhouse, Male)</i></p>	
<p>Q2: Can you provide an insight of the process you go through when selecting new items into the menu, specifically the ones that represent diverse cultural cuisines.</p>	<p><i>“The way our shop goes through this process is we have a team of managers that collaborates to focus on enhancing our offerings with related asian flavors. We incorporate diverse ingredients creating a multicultural blend experience that makes the flavor more rich, while embracing cultures around Asia. One of our fan favorite dishes, Katsu Chicken curry, we use Japanese Panko crumbs, paired with Thai chili peppers making this a flavorful rich spicy flavor. These dishes take more than over 100 trials to perfect, as we really value the quality of our food.”</i> <i>(P1, Ramen shop, Male)</i></p> <p><i>“Our team goes through a fairly thorough research on original</i></p>	<ol style="list-style-type: none"> 1. Research and creativity- Owner researches Japanese ingredients, combining with creativity 2. Balance authenticity and innovation, Tempura cheesecake would be a example 3. Cultural Diversity celebration- celebrate the diverse cultures through the menu 4. Alignment of Japanese steakhouse identity

	<p><i>Japanese ingredients, combining it with creativity and paying attention to the mixture of authenticity and empathy. Our Tempura Cheesecake was a fusion that combined elements of iconic Japanese tempura with cheesecake from the United States. (P2, Japanese steakhouse, Male)</i></p>	
<p>Q3: How do you strike that balance of ensuring cultural representation while making the dishes taste as authentic as possible?</p>	<p><i>“Having a balance between these both is one our main approaches. Through the choice of our ingredients, it represents the principles for both of these two cuisines. For example, combining the traditional Taiwanese ramen methods with the authentic Japanese sushi making techniques allows us to create a balanced fusion. It's about preserving the traditions for both of our cuisines making sure our dishes bring out the authentic flavors of both cultures.”</i> (P1, Ramen shop, Male)</p> <p><i>“I personally select ingredients that show the essence of Japanese culinary traditions. Every new dish chosen was taken through careful consideration of mixing the traditional flavors with the inevitable touch of the modern cuisine. This is all about finding the sweet spot in between both of these while also satisfying our customers.”</i> (P2, Japanese steakhouse, Male)</p>	<p>1. Ingredient selection- Carefully selecting ingredients that capture the authentic essence of the dishes</p> <p>2. Customer experience- Enhancing dining experience for customer so they can enjoy authenticity and exploring diverse flavors</p> <p>3. Innovating but not forgetting- Commitment to innovating a menu but not forgetting the authenticity of the dishes.</p>
<p>Q4: Can you share any challenges you've faced in maintaining a</p>	<p><i>“ One issue was having access to high quality and authentic ingredients for both my Taiwanese ramen and sushi.</i></p>	<p>1. Finding authentic ingredients</p> <p>2.. Training</p>

<p>culturally diverse menu, and how have you overcome them to provide a well-rounded dining experience?</p>	<p><i>This requires a lot of effort to secure the right components for our dish to make them taste as authentic as possible. Balancing traditional techniques of each cuisine while ensuring the fusion will present its difficulties. To overcome these obstacles, we train our staff and collaboration, especially when the dishes require a combination of both culinary skills. We also look for experienced chefs, specifically ones that have worked in the Taiwanese or Japanese industry before as they have more experience leading to better experience overall. I frequently test restaurants with the same meals I want to serve to gain knowledge and strategies to improve our dishes..”</i> (P1, Ramen shop, Male)</p> <p><i>“The diversity of our menu in a Japanese steakhouse is not simple because of the need to have precise and unique ingredients. The tricky part is the hunt for the original/authentic ingredients to maintain the real tastes in our dishes. Finding a balance between original Japanese crafting techniques and modernizing them causes its own challenges. Continuously adapting to the changing preferences and needs of our diverse customer groups is still an ongoing challenge for us. .To eliminate these obstacles, I have personally traveled to Japan myself tasting their Japanese steakhouses to get the real and most authentic tastes.</i></p>	<p>staff/Collaboration-Talked about finding right staff</p> <p>3.Menu Innovation with tradition-Adding new items while preserving Taiwanese/Japanese essence</p> <p>4.Modern preferences-Balancing between originality and modern preferences</p>
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	<p><i>Similarly, I have worked in multiple Japanese steakhouses to get a deeper understanding and insights into their cooking styles. We take this active research seriously so as to maintain the highest standards of authenticity and make sure we provide a well rounded dining experience that represents the unique traditions of Japanese cuisine.” (P2, Japanese steakhouse, Male)</i></p>	
<p>Q5: How has the diversity of your menu changed throughout the past years and what factors have contributed to changes or expansions in the representation of different cultural cuisines?</p>	<p><i>“The shift is a consequence of carefully choosing genuine ingredients, confirming that every dish represents the culture of Taiwanese and Japanese culinary traditions. Customer feedback and preferences are the main factor, helping us to provide a satisfying dining experience. WE often do surveys from time to time asking for recommendations of dishes.”</i> <i>(P1, Taiwanese Ramen shop, Male)</i></p> <p><i>“We are adaptive, we take into consideration our customer eating habits while preserving Japanese cuisine. Besides this, we also add items into our menu through exploration of popular dishes that are seen through social media in Japanese culture. As certain trends gain attention, we consider integrating them into our menu. This commitment allows us to introduce new elements, which matches with authenticity and ensures that there is a balance between the new and old, inspired by our customer feedback and global</i></p>	<p>1. Customer feedback/preference- Menus are often changed through customer feedback 2. Trends-Adapting to culinary trends and global trends</p>

	<p><i>culinary influences.” (P2, Japanese steakhouse, Male)</i></p>	
<p>Q6: From your perspective, how do you assess the impact of cultural diversity on the overall success and identity of your restaurant?</p>	<p><i>Our fusion of Japanese and Taiwanese dishes not only appeals to many customers but also makes us different from the other restaurants. In the industry where many of our competitors are focused on one culture, our own way of approach stands out, becoming a part of our brand. This is a distinctive feature, which still creates our success that is shown through our positive reviews and the loyalty of many of our customers. Many of our customers say how it is so nice that our restaurant can satisfy their needs of both cultures of food.”</i> <i>(P1, Taiwanese Ramen shop, Male)</i></p> <p><i>“Cultural variety is what makes our restaurant stand out and succeed. By giving a wide variety of food inspired by real Japanese cuisine we get to satisfy many tastes at the same time, which is our major advantage. As the company continues to grow, the positive reviews from our customers manifest how cultural diversity enhances our restaurant reputation and the overall success.”</i> <i>(P2, Japanese steakhouse, Male)</i></p>	<p>1.Success-Cultural diversity plays a huge role in success of both 2. Stands out in the industry 3,Loyal Customers- Cultural diversity is a key factor in maintaining loyalty.</p>

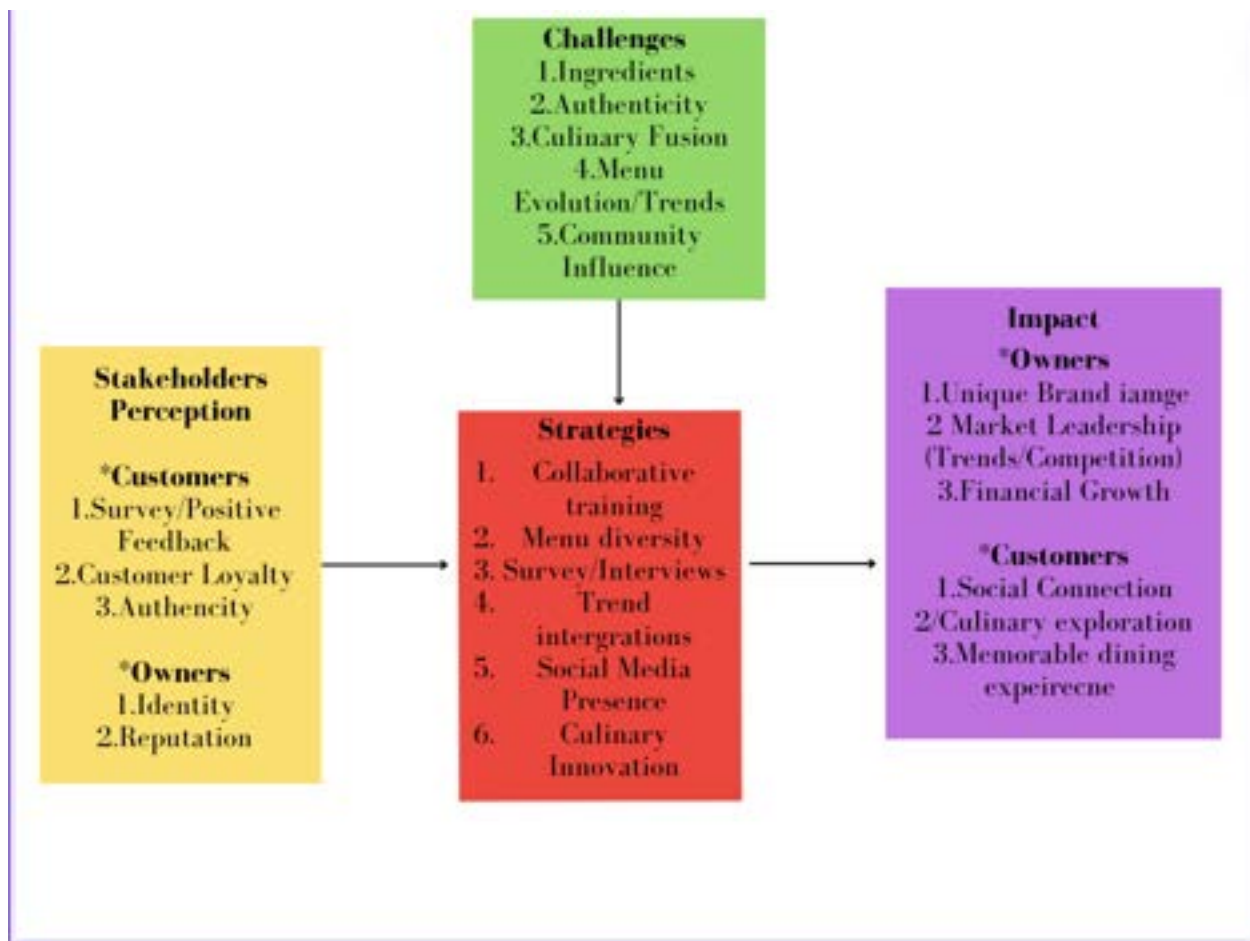
<p>Q7: How do you measure the impact of cultural elements in menu selections on customer satisfaction and the restaurant's reputation in the community</p>	<p><i>“The success is monitored through our popular menu choices and feedback. Customers are the ones that make us adjust our menus in line with a balance between cultural authenticity and modern tastes. Our social media account allows us to measure community responses/opinionos, making us able to adapt and meet our diverse audience expectations.”</i> (P1, Taiwanese Ramen shop, Male)</p> <p><i>“We evaluate them through tracking the popularity of individual dishes and talking to our customers directly. Feedback and recurring orders for culturally influenced menu items show the satisfaction of customers. Our participation in local events and community meetings gives us insights into how the cultural representation of our restaurant has made us highly reputable in the community.”</i> (P2, Japanese steakhouse, Male)</p>	<ol style="list-style-type: none"> 1.Menu popularity analysis- Finding most ordered dishes in the menu 2.Adapting to customer feedback 3.Social Media presence- Helps them promote themselves and find feedback 4.Direct feedback- Interviews with customers observing positive feedback 5. Community presence- Reputation is good and measured through events
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Summary of Interview

Through interviews we have learned the central factors triggering the market of multi-ethnic cuisine in the restaurant business. Participants with this philosophy prefer to ensure that they acquire original and original ingredients to maintain authenticity of the ethnic dishes. Besides that, they also stress out on merging the conventional cooking process with new aspects. Furthermore, team building activities with a culturally sensitive theme overlay achieves the most vivid dining atmosphere possible. Nevertheless, the hospitality business and its evolving nature exhibit multicultural restaurants constantly improving and updating their menus, taking into consideration remarks from customers, and masterfully applying social media to remain current with world cuisines. Communities are also becoming integral in this process, and strategic approaches that support community cultural connections and create more presence in the community can be enhanced.

Discussion

The insights gained from the literature review, survey, and interview unveils the key factors into shaping multicultural menu choices in the US restaurant industry. This created the framework diagram below.



Discussion

Multicultural restaurants struggle with various challenges, in their quest to provide a diverse and authentic culinary experience. A significant issue is their challenge to source high quality and authentic ingredients. Providing authentic dishes like Taiwanese ramen and sushi requires a lot of effort to ensure availability of the right ingredients that define diverse cuisines. Traditional culinary practices are combined with fusion elements through a careful selection of ingredients, which shows their commitment to serving the authentic meal.

Owners of the restaurants quite often face the difficulties of creating the balance of cultural cooking traditions. Preserving the authenticity of each cuisine while adding innovative touches is a challenging task. The process involves staff training, collaboration, and hiring chefs with previous knowledge of cultures and cuisines. This blend of cooking methods is intended to establish a one of a kind dining space with inclusive and diverse flavors.

In the dynamic landscape of the hospitality industry, menu evolution and trends are a challenge that arises. Menus are developed based on the changing culinary trends and customer feedback. Meeting the changing tastes, trends, and culinary innovations requires a thorough knowledge of the market. The multi-cultural restaurants deal with the challenges by actively monitoring menu popularity, adapting to customer feedback, maintaining an active social media presence and staying up to date with food and global trends.

Multicultural restaurants are a huge part of the communities as they serve, and are influenced by those communities which shape their challenges. The diversity of the local community is reflected in the ingredients, authenticity and culinary techniques. Restaurants frequently struggle with the balance between community expectations and authenticity. Successful approaches to these challenges result in a positive community presence, which contributes to the restaurant's overall success and its integration within the highly diverse cultural landscape.

Even with these challenges present, there are many effective strategies that can be implemented to navigate through their complexities. Collaborative training can be one of the cues, fostering techniques to improve staff knowledge, and enrich the knowledge of different culinary traditions. This technique involves cultural training sessions that enable chefs and staff to share their knowledge and expertise. Through the development of a culturally aware team, restaurants provide an authentic and inclusive dining experience for customers.

Moreover, menu diversity can be employed with an ongoing process of menu expansion and diversification to satisfy varied tastes and preferences among different cultures. Establishing dishes from different cuisines guarantees a dynamic and inclusive dining experience bringing together a wide range of customers.

Restaurant owners can also use surveys or interviews to gain information from their customers, which helps them to know what they like and dislike, how satisfied they are, and what needs to be improved. This strategy is designed to personalize the products to the customers likings, improving the whole dining experience and ensuring customer loyalty.

Listening to the trends in the culinary and market industries is an essential strategy for multicultural restaurants. The integration of current trends in menu offerings, culinary techniques and customer experiences makes the place relevant and attractive. This strategy alignment with trends helps the restaurant to remain competitive and to attract a broad customer base.

Achieving a strong social media presence is a huge role for multicultural restaurants. By being present on platforms such as Instagram, Facebook, and X these restaurants interact with customers presenting various offerings and take advantage of positive reviews and recommendations. A strong social media presence boosts visibility, attracting new customers, and creates a feeling of community among the customers.

Culinary innovation is a core strategy for multicultural restaurants seeking to differentiate themselves from other competitors. By experimenting with different flavors, presentation styles and culinary techniques these restaurants are able to showcase their creativity and give customers something unique. Strategic culinary innovation forms the restaurant's identity and generates a feeling of excitement for clients.

In understanding stakeholders perceptions, the customer's perspective is crucial. Crafting a unique identity includes presenting a unique dining experience through a multicultural menu. This selection of multicultural elements distinguishes the restaurant's mission, creating an unforgettable and unique brand that stands apart from the rest in the competitive food industry. Reputation of restaurants weighs on the owners shoulders as well. It is not only food related but also includes how well the restaurant integrates with the community and the authenticity it brings to the table. A positive reputation not only attracts customers, but also develops loyalty, making it a crucial factor for owners seeking long-term success in this industry.

Through the implementation of these strategies, owners can experience different aspects of impact. Multicultural restaurants specifically focus on building a unique brand image that differentiates them in a competitive market of the culinary industry. Through their various cultural cuisines, they make themselves stand out and memorable. The strategic focus on a unique brand identity increases brand recognition, loyalty, and ultimately market appeal.

Leading the market requires following the culinary trends and successfully negotiating the competition. Multicultural restaurants purposefully place themselves as innovators, adjusting to changing customer preferences and being ahead of industry trends. This smart strategy helps them stay on the top in the dynamic restaurant market and draw a wide customer base looking for innovative and diverse dining experiences.

The impact of financial growth is the main objective of multicultural restaurants. With an emphasis on diverse menu options, marketing and keeping up with food trends, the restaurants aim for stable financial development. With this strategic approach, the success of the business and its profitability are secured, which ensures long term success and further investment into culinary innovation and customer experience.

Now that we have covered the impact through restaurant owners, let's discuss the impact for regular customers. Multicultural restaurants don't just serve food, rather, they create a place of interaction and accomplishment for diverse cultural experiences. The restaurants that show the

diversity of cultures by providing the ambiance that is conducive to celebrating various cultures create a unique setting where customers from diverse backgrounds can meet, interact and learn from each other about the diversity of global cuisines.

Multicultural restaurants choose to present the concept of culinary exploration as their distinctive feature. The customers are motivated to get out of their usual culinary comfort zones and try something different with the flavors from every place of the world. This strategic play on customer curiosity, exploring different and unusual foods, only adds to the thrill of it all. The food journey, in which the customer explores the food, becomes a crucial aspect of their journey, refining their palate and enhancing their cultural understanding through their food.

The primary goal for the restaurants is to offer unforgettable dining/eating experiences. The multicultural restaurants plan their menu, interior design, and customer service in such a way that their clients would be satisfied and leave the place with an unforgettable experience. If it's a restaurant that shows or says, their unique cultural presentation, personalized service, or unique menu options, the purpose is to make each visit special. This emphasis on leaving customers with long lasting positive memories reinforces customer loyalty, good reviews and sustained business growth.

Limitations and Future Directions

This study recognizes the possible weaknesses that may affect the generalization of its findings. The data collected with the customer surveys from restaurants pose a risk of sample bias and make the relevance of the results to other multicultural restaurants questionable. Another limitation is the response bias, where customers might give socially desirable answers that may mess up the accuracy of the data. In addition to this, the study might face difficulties where it will fail by some few customers who in no way are ready for filling their surveys leading to limited data representation.

Studies in the future could go beyond any single restaurant to assess the diverse multicultural settings. Studying a range of different contexts would help in the discussion about how cultural difference determines the menu selection and also customer satisfaction. In order to reduce the risk of response bias, future researchers might use creative methods such as using anonymous surveys or experimental designs. Additionally, focusing on the different approaches to data gathering like in depth interviews or studies may enhance the qualitative aspect.

In order to minimize the effect of possible non response biases, future research could focus on opinions held by the customers who do not participate. Understanding their reasons for not participating would add a lot of helpful context to the overall analysis. Longitudinal studies may inform the trends in the evolving multicultural restaurant landscape by tracking patterns of changes that vary with time.

Conclusion

This research is devoted to the investigation of the influence of multicultural menu choices on the US restaurant business. It determines and measures the factors that influence the

consumer decisions and satisfaction in today's culturally diverse market. The main focus is to investigate and find the factors underlying menu choices, with a focus on multicultural restaurants in tourist destinations. The study combines qualitative and quantitative methodologies through literature reviews, online surveys and interviews.

The framework of this study consists of various aspects, each serving to enrich the discussion on the elements that go into the multicultural menu selection process. These aspects include authenticity, brand perception, service and quality, customer satisfaction, cultural elements, and many more success factors. Through the process of conducting interviews, literature reviews, and surveys, valuable insights were extracted from customers and the stakeholders involved in the restaurant business.

As the restaurant industry evolves, these findings are crucial for future owners. Identifying the importance of authenticity, location, and customer recommendation contributes to developing strategies for your business and improving customer satisfaction. The study also underlines the importance of understanding and meeting the requirements of the customers' preferences who frequently dine out at restaurants, emphasizing the importance of meeting their specific requirements in the industry.

In conclusion, this study takes into account the limitations, but it does open up an opportunity for future researchers to conduct an in-depth research on the intricacies of how menu choices affect customer satisfaction in multicultural restaurants. The insights not only spell out the power of multicultural menu options, but also affirm the general knowledge of the fast-paced and multicultural restaurant industry. The study is able to identify the key factors and strategies and as a result present an opportunity for companies to rise as leaders in an ever dynamic market. Further studies could amplify these results and reveal more dynamics which are vital in obtaining success in the rapidly changing multicultural cuisine environment.

A Review of Techniques to Optimize Transition Metal Chalcogenide Catalysts for Effective Photoelectrochemical Water Splitting By Anika Deshpande

Research Question: How can the surface of transition metal chalcogenides be engineered to improve heterojunction formation, defect tuning, photovoltage and photocurrent for effective water splitting?

Abstract

Water splitting is a hydrogen generation process that uses sunlight to separate water into its components: hydrogen and oxygen. This process takes place when a photoelectrode produces electrons from sunlight in the presence of an electrolyte solution. These electrons engage in the oxygen evolution reaction (OER) at the anode, leading to the generation of oxygen gas. Simultaneously, positively charged holes (vacancies in the electron structure) partake in the hydrogen evolution reaction (HER) at the cathode, resulting in the production of hydrogen gas. While this process elicits appeal due its sustainable nature, it is premature for industrial synthesis due to the instability, cost inefficiency, and unscalable nature of the current catalysts used.

Therefore, this research examines a class of earth-abundant and cost-effective semiconductor materials known as transition metal chalcogenides (TMCs) that could potentially serve as alternative catalysts to the current ones. Through an analysis of surface engineering techniques for champion materials in the field, a relationship between a chosen material and an optimization technique is found, leading to the establishment of Sb_2Se_3 as a superior catalyst and sulfur richness as the best optimization technique for it. In addition to highlighting the untapped potential of TMC's, this research also lays out prospects for future research to rectify knowledge gaps about solution environment and long-term effects of electrolysis within the field. Systematic experiments involving finding the impact of pH, solution composition, and ionic strength on semiconductor and catalyst behavior in water splitting, aim to optimize their performance. Additionally, addressing the challenge of defects during prolonged electrolysis, a multifaceted approach includes in-situ characterization, accelerated aging experiments, and computational modeling.

1. Introduction

The onset of global warming urgently requires clean and cost-effective energy resources to replace traditional fossil fuels. Hydrogen, distinguished by its high gravimetric energy density and carbon-free chemical composition, has emerged as a preferred clean energy option. Leveraging hydrogen to reform the energy supply structure of every aspect of our society is believed to be the most promising way to achieve zero carbon by 2050. Currently, steam reforming of fossil fuel is the prevalent process to produce hydrogen for industry, which inevitably emits CO_2 due to both the stoichiometry of the reaction and the fossil fuel combustion required for heat supply. One of the ideal ways to avoid these CO_2 emissions in hydrogen production is electrochemical water splitting driven by renewable energy sources like solar light.

Solar light-assisted photoelectrochemical (PEC) water splitting is a process that uses sunlight to directly dissociate water into hydrogen and oxygen. The process involves a photoelectrode absorbing sunlight to generate electrons, coupled with an electrolyte solution. The electrons participate in the oxygen evolution reaction (OER) at the anode, resulting in the production of oxygen gas, while positively charged holes (vacancies in the electron structure) contribute to the hydrogen evolution reaction (HER) at the cathode, yielding hydrogen gas. The appeal of water splitting lies in its sustainable nature for hydrogen generation.

While solar light-assisted PEC water splitting stands out as a highly efficient approach to produce hydrogen and oxygen, it remains insufficient in industrial applications because of the inherent instability of catalysts that drive the reaction. As found in *Recent Advances in Noble Metal-Based Electrocatalysts for Efficient Hydrogen Evolution Reaction*, Precious metals, notably platinum (Pt), iridium (Ir), ruthenium (Ru), and their alloys, have been recognized as optimal electrocatalysts due to their exceptional activity and stability for water splitting (Changqing Li and Jong-Beom Baek). However, the limited availability and high cost of these precious metals impose significant constraints on their widespread practical use at an industrial scale. Consequently, the quest for economically viable and sustainable alternatives to these precious metal catalysts has become imperative for the advancement of solar-driven PEC water splitting technologies in real-world applications. Substantial research endeavors have thus been directed towards increasing the conversion efficiency of these electrocatalysts, as evidenced by the abundance of publications in this field.

One way to achieve this is *via* advancing the design of highly efficient, scalable, and stable materials tailored to effectively catalyze PEC water splitting reactions. In particular, transition metal chalcogenides (TMCs) are a class of compounds featuring transition metals bonded with chalcogen elements, exhibiting semiconductor properties with layered structures. These materials offer a cost-effective and Earth-abundant alternative to the currently employed precious metals, as their structural versatility makes them promising electrocatalysts for water splitting. TMCs efficiently absorb and activate water molecules, making them potential catalysts for both the Oxygen Evolution Reaction (OER) and the Hydrogen Evolution Reaction (HER). Moreover, they demonstrate remarkable stability, maintaining catalytic activity and structural integrity even under the harsh conditions inherent in the water splitting process. Their highly crystalline structures also contribute to well-defined electronic band structures, resulting in heightened electrical conductivity.

2. Proposal

Because transition metal chalcogenides are semiconductors, their photocurrent density is intricately shaped by crystal size, morphology, and orientation, leading to superior photocurrent characteristics. Specifically, the presence of heteroatoms within their crystal structures allows for effective doping, enabling substantial alterations in electronic properties. This doping can tune parameters such as bandgap, thereby optimizing electric conductivity and catalytic activity, but is relatively unexplored. Additionally, defect engineering is possible for these materials, which

benefits both intrinsic catalytic activity and electric conductivity. Despite this, it remains challenging to further improve the electrocatalytic activity and long-term stability of TMCs, especially in a practical water electrolyzer. However, TMCs can be readily synthesized as nanocrystals. In addition to the increased surface area that comes with smaller size, it has been shown that different synthetic techniques can alter the morphologies/surfaces of these nanomaterials. For example, in *Exfoliated Molybdenum Disulfide-Wrapped CdS Nanoparticles as a Nano-Heterojunction for Photo-Electrochemical Water* by Sukdev Dolai, Pradip Maiti, and colleagues, liquid phase exfoliation using chemical vapor reaction (CVR) with chalcogen powders was used to synthesize TMCs with more exposed surface active sites, which enhanced intrinsic high electrocatalytic activity for both HER and OER.

In this research paper, with the help of my research mentor, I will analyze how engineering the surface of nanosized transition metal chalcogenides leads to improved catalytic activity with regards to PEC water splitting. I will then propose an optimal route to achieve a viable TMC electrocatalyst.

3. Background

Looking at the current state of the field, it is important to assess the champion materials for electrochemical water splitting, as it often provides important insight for future research and optimization. As aforementioned, TMCs show great promise as next generation catalysts for electrochemical water splitting due to their noteworthy electrocatalytic capabilities and distinctive features, in addition to their environmental and economic benefits. This section will assess the current champion TMC materials.

First, Sb_2Se_3 , a layer-structured semiconductor with an orthorhombic base, is considered one of the leading TMCs for water splitting. Sb_3Se_2 exhibits unique atomic arrangements where each Sb and Se atom is surrounded by three opposing atoms. The antimony atoms, specifically, form a trigonal pyramidal coordination with the surrounding selenium atoms. The crystal lattice showcases layered structures held together by weak van der Waals interactions between the layers, rendering it as a heterojunction catalyst. Notably, Sb_2Se_3 has earned the recognition as a benchmark material due to its remarkable achievement of one of the highest photocurrent densities-30 mA cm^{-2} at 1 vs Ag/AgCl electrode, as found by Mohsin Ali Marwat, Muhammed Humayan, and others, in *Advanced Catalysts for Photoelectrical Water Splitting—under simulated light*.

The exceptional photocurrent density can be attributed to the efficient charge transport facilitated by well-ordered vertical [001] nanowires of Sb_2Se_3 , a component of Sb_2Se_3 . Moreover, the direct bandgap resulting from its layered structure ensures that electrons and holes, generated by absorbed photons, exhibit high mobility. This characteristic allows them to contribute to the photocurrent without requiring additional energy to reach the band extrema, a quality which is highly desirable in water splitting. The strong anisotropy of Sb_2Se_3 becomes evident as it demonstrates greater mobility in the [001] direction compared to [010] and [100] (Marwat *et al.*

12023). The high mobility and anisotropic characteristics of Sb_2 allows for directional control of reaction pathways, which can enhance the overall efficiency of the water splitting process.

The optimization of Sb_2Se_3 photocathodes involves experimenting with various solvent combinations. Marwat and Humayan used 2-mercaptoethanol and ethylenediamine. By manipulating the proportion of selenium to antimony precursor, enhanced photocurrents were achieved. The resulting Sb_2Se_3 material displayed a “compact film-like shape” (Marwat *et al.* 12023) oriented along [001], revealing a high density of photocurrent. This multifaceted approach not only shows the material’s unique properties but also shows the potential for advancing the practical applications of water splitting.

Another promising material is Pyrite NiS_2 , which crystallizes in the hexagonal space group. A noteworthy feature of NiS_2 is its ability to undergo electronic structure reconfiguration, transitioning from typical semiconductive characteristics to metallic characteristics through the introduction of vanadium (V) displacement defects, as described in *A Mini Review on Transition Metal Chalcogenides for Electrocatalytic Water Splitting: Bridging Material Design and Practical Application* by Yongjie Liu, Yajie Guo, and others, Experimental temperature-dependent resistivity and theoretical density functional theory calculations have confirmed this transformation. Elaborate X-ray absorption spectroscopy measurements further elucidate that the reconfiguration of NiS_2 ’s electronic structure is rooted in electron transfer from doped V to Ni sites, making Ni sites electron rich. (Liu et al 2617)

This unique characteristic makes Pyrite NiS_2 particularly suitable for water splitting. The metallic V-doped NiS_2 nanosheets have emerged as one of the most promising non-noble-metal bifunctional electrocatalysts. As observed in *A Mini Review on Transition Metal Chalcogenides for Electrocatalytic Water Splitting: Bridging Material Design and Practical Application*, these nanosheets exhibit exceptional electrocatalytic activity, displaying overpotentials of approximately 290 mV for OER at 10 mA cm^{-2} in a 1 M KOH solution. (2617) The effectiveness of Pyrite NiS_2 in water splitting is due to the shift in its electronic structure from semiconductive to metallic. This transition has been substantiated by both temperature-dependent resistivity experiments and theoretical calculations, highlighting the material’s enhanced conductivity and electrocatalytic performance in facilitating the crucial OER step during water splitting processes.

NiSe is another material that is suitable for water splitting. The significance of NiSe in water splitting arises from its exceptional performance in the HER when compared to other Ni-based (oxy)hydroxides and selenides. The distinctive hexagonal crystalline structure, inherited from the precursor $\text{Ni}(\text{OH})_2$ nanosheets supported on nickel foam (Fig 1), serves a dual purpose. As found in *A Mini Review on Transition Metal Chalcogenides for Electrocatalytic Water Splitting: Bridging Material Design and Practical Application* by Yongjie Liu, Yajie Guo, and others, , these prefabricated nanosheets facilitate the transformation of ultrathin 2D non-layer NiSe through selenization, acting as both the nickel ion source and the skeleton template.

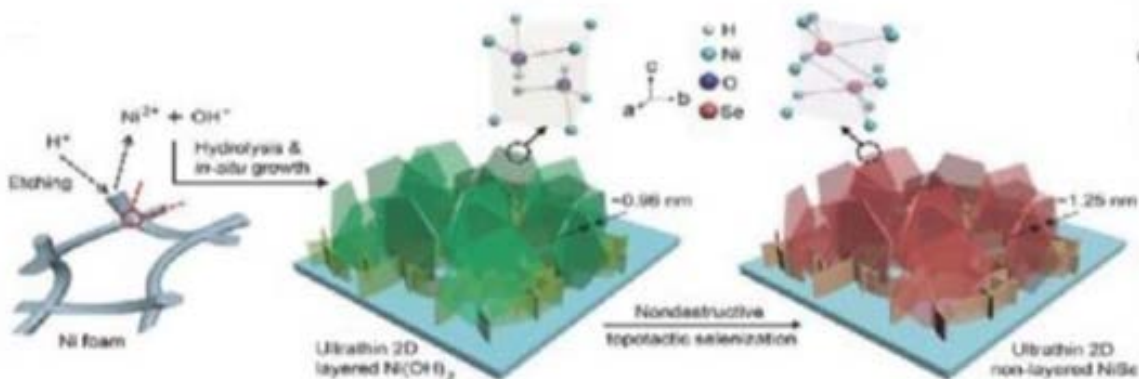


Fig 1: This figure shows prefabricated Ni(OH)₂ nanosheets supported on nickel foam. Engineered nanosheets play a dual role, acting as both a source of nickel ions and a template. They guide the formation of NiSe on nickel foam, creating a durable hexagonal structure that facilitates overall efficiency in water splitting by sustaining catalytic activity. (Liu *et al.* 2612)

The resulting NiSe, maintaining the morphology of the Ni(OH)₂ precursor, emerges as a catalyst with superior electrocatalytic activity for the HER. The existence of large cavities in its structure, coupled with the weak bonding force, contributes to the overall efficacy of the NiSe in promoting hydrogen evolution. Additionally, the hybrid catalysts formed during this process often display distinct interfacial effects and synergetic effects, further enhancing their electrocatalytic performance. In essence, NiSe, derived from a well-designed precursor, stands out as a promising semiconductor material, showcasing remarkable activity and structural characteristics that contribute to efficient hydrogen evolution.

Finally, the semiconductor material CZTS-Ag₂S possesses distinctive characteristics in both surface chemistry and crystal structure that contribute to its efficacy in water splitting applications. as found in *Cu₂ZnSnS₄-Ag₂S Nanoscale p-n Heterostructures as Sensitizers for Photoelectrochemical Water Splitting* by Xuelian Ju, Jingjing Liu, and others, the Ag₂S nanocrystals within the CZTS-Ag₂S configuration examined at the [311] axis exhibit a quasi-spherical geometry, with an average particle size of 12 nm. The crystal structure of Ag₂S nanocrystals within the CZTS-Ag₂S configuration exhibit a quasi-spherical geometry, with an average particle size of 12 nm. The crystal structure of Ag₂S, with its monodisperse morphology, is characterized by lattice parameters of $a = 0.4127$ nm, $b = 0.6699$ nm, and $c = 0.7838$ nm, with space-group symmetry P21/c, $\alpha = \gamma = 90^\circ$, and $\beta = 99.67^\circ$. Simultaneously, the power spectrum of CZTS nanocrystals displays wurtzite-phase when examined at the [11-2-3] axis, featuring lattice parameters of $a = b = 0.3839$ nm and $c = 0.6339$ nm, with a space-group symmetry of P63mc (Ju *et al.* 10558).

The effectiveness of CZTS-Ag₂S for water splitting is attributed to its p-n heterostructure, which serves as a sensitizer to enhance the photocurrent response in PEC water splitting. The

designed CZTS-Ag₂S p-n heterojunction catalysts form a type-II band alignment, facilitating charge separation and thereby improving the PEC performance of the heterostructure. Notably, the TiO₂/CZTS-Ag₂S heterostructure catalyst (H2 sample) demonstrates superior performance, exhibiting a photocurrent density of 0.15 mA cm⁻² at 0.5 V. As seen in Fig 2, this performance surpasses that of TiO₂ (0.03 mA cm⁻²) and TiO₂/CZTS (0.06 mA cm⁻²) (Ju *et al.* 10558), confirming the enhanced PEC performance under visible light irradiation.

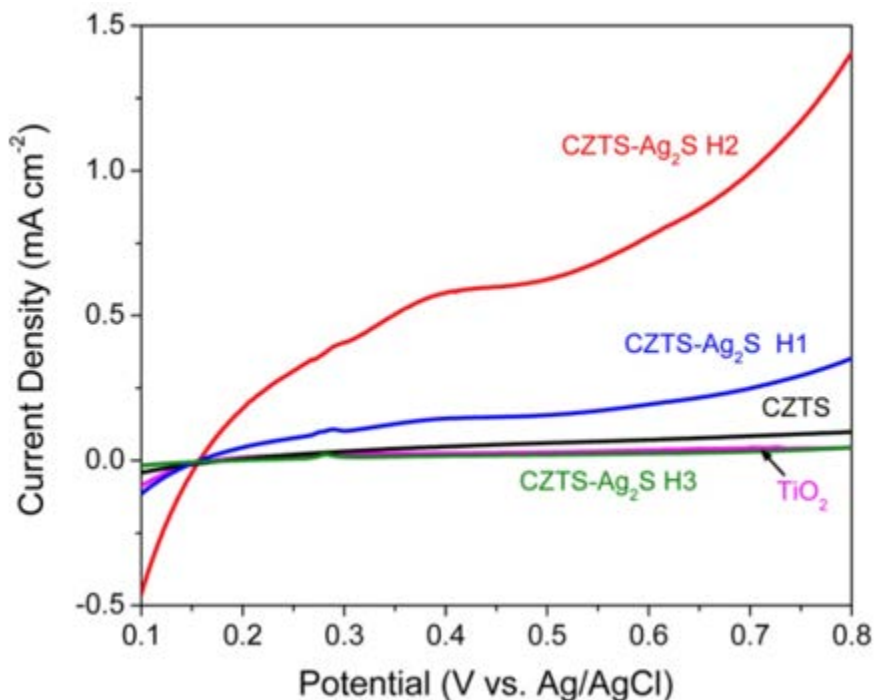


Fig 2: This figure captures the exceptional performance of CZTS-Ag₂S attributed to a robust p-n heterostructure, especially TiO₂/CZTS-Ag₂S (H2) which surpasses traditional counterparts under visible light.

4. Methods/Materials

Transitioning from the examination of the champion TMCs, we must explore optimization strategies for these semiconductor materials, to achieve increased PEC activity and overall efficiency of the water splitting process:

First, composite materials can increase PEC activity because the addition of nanoparticles with desirable characteristics can optimize the effectiveness of the composite material as a whole. In *Exfoliated Molybdenum Disulfide-Wrapped CdS Nanoparticles as a Nano-Heterojunction for Photo-Electrochemical Water Splitting*, Sukdev Dolai, Pradip Maiti, and others found that by wrapping CdS nanoparticles by few layer MoS₂, the absorption spectra in the visible range of the CdS particles would increase the absorption coefficient of MoS₂@CdS composites, enhancing PEC performance as seen in Fig 3.

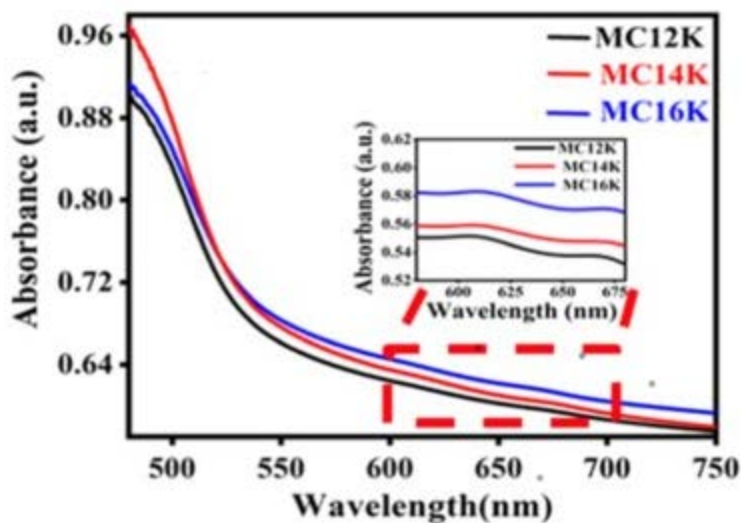


Fig 3: This figure shows CdS nanoparticles wrapped with a few layers of MoS₂. The absorption spectra in the visible range are increased, enhancing the effectiveness of MoS₂@CdS composites by maximizing photon capture to improve overall PEC performance (Dolai *et al.* 441).

Similar to the CdS nanoparticles, janus particles can also facilitate efficient light absorption. In addition, they improve charge carrier separation, and allow for customization of semiconductors due to their dual functionality. This dual functionality allows for tailored interactions with different materials and environments. In *Janus WSSe Monolayer: An Excellent Photocatalyst for Overall Water Splitting* by Lin Ju, Mei Bie, etc., strain engineering (application of both compression and tensile strains) was used to optimize the optical absorption of the Janus WSSe monolayer. The external tensile strains were found to increase the solar-to-hydrogen energy conversion efficiency by pushing the electrons (holes) to the Se (S) layer by the built-in polarization field, which resulted in the lower binding energy of excitons. (Fig 4) Therefore, the charge carrier separation of photoexcited electrons and holes is improved along with the photocatalytic efficiency. (Figs 5 and 6)

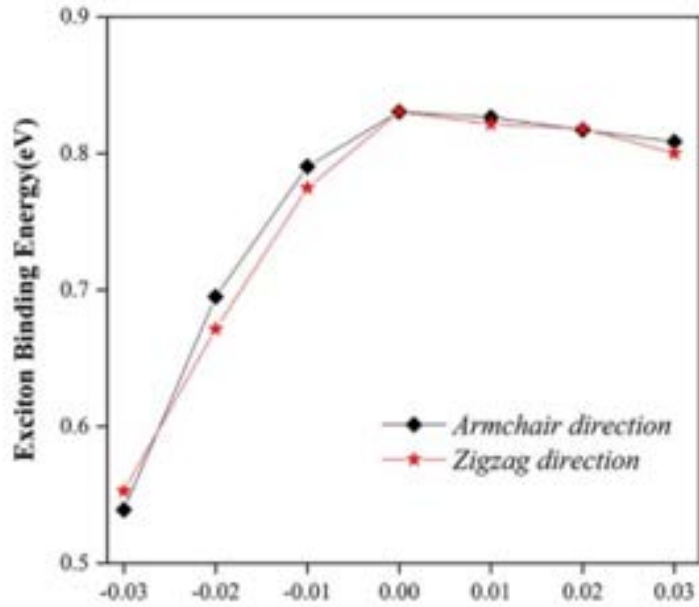


Fig 4: This figure illustrates the impact of strain engineering on the Janus WSSe monolayer. External tensile strains optimize the binding energy of excitons (electron-hole pairs), boosting the separation of photoexcited electrons and holes for improved photocatalytic efficiency. (Ju *et al.* 29337)

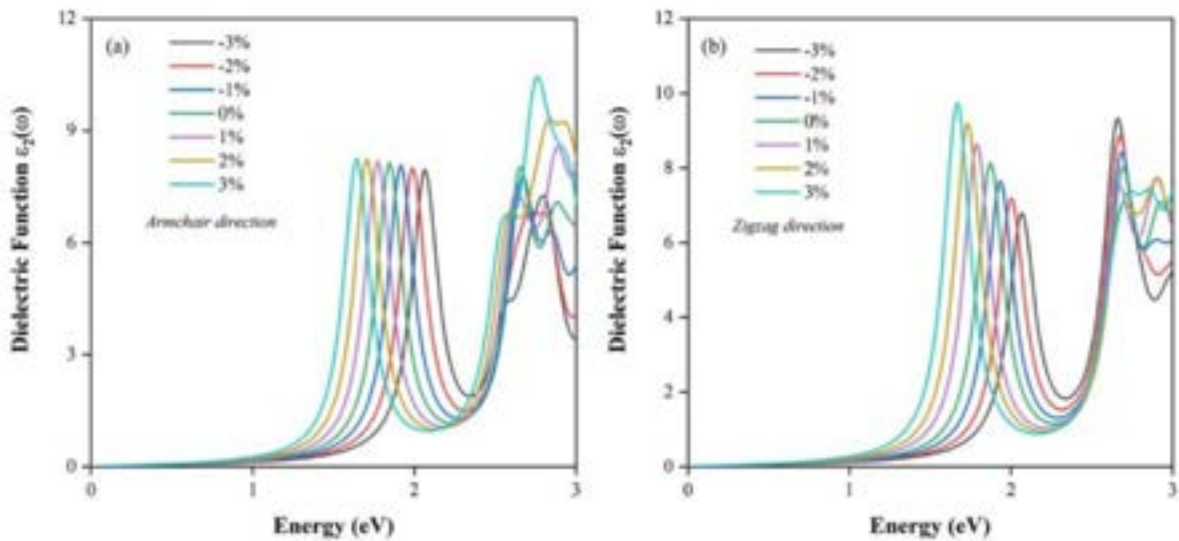


Fig 5: This figure shows the improved dielectric properties of WSSe monolayers, a key factor in optimizing their performance for water splitting. These properties contribute to the overall efficiency of Janus WSSe monolayers in separating photoexcited electrons and holes, crucial for successful water splitting processes. (Ju *et al.* S3)

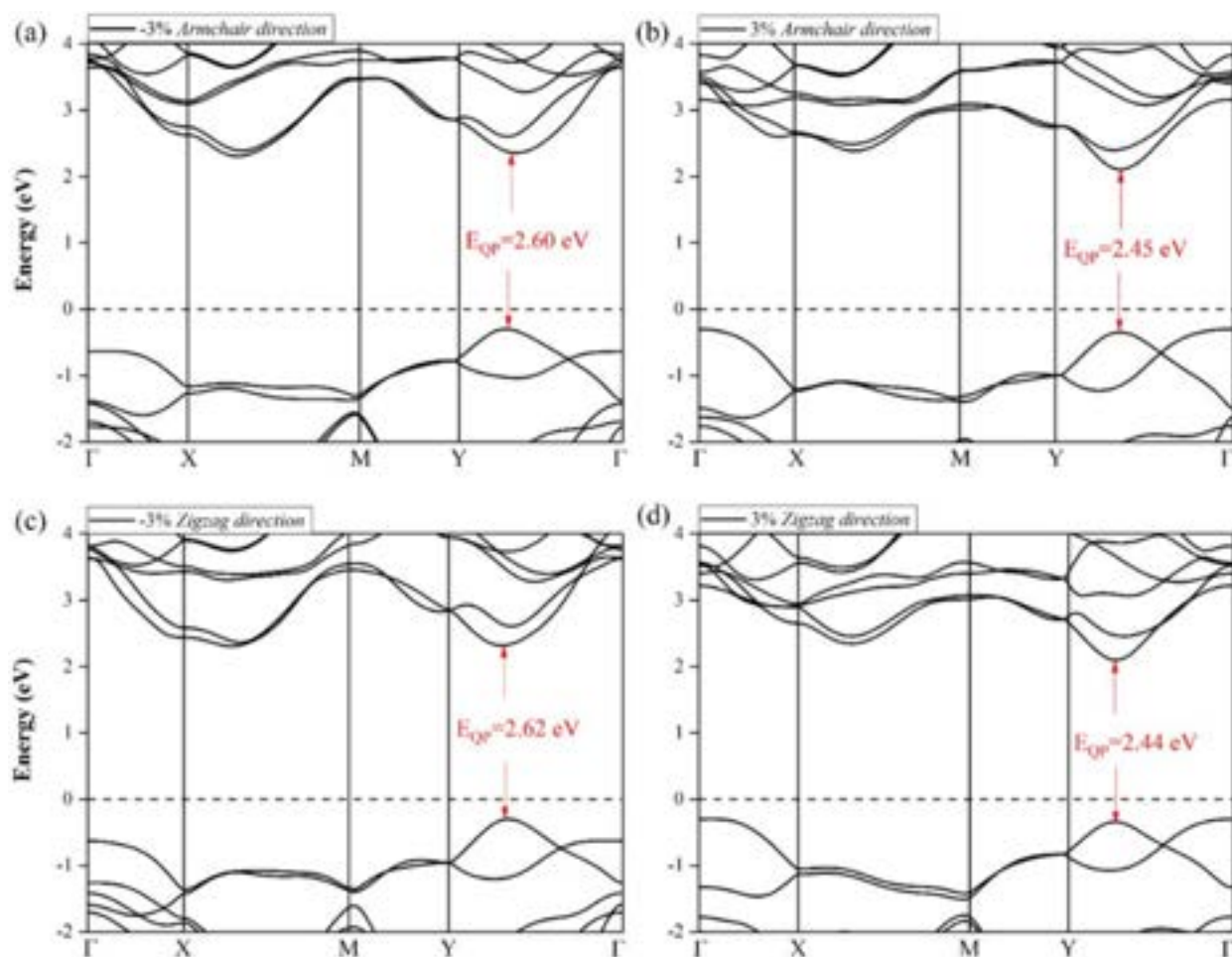


Fig 6: This figure displays band structures of strained monolayers in different directions. The indicated values show how applying strain can adjust the bandgap, critical for better separating charged particles. This characteristic improves the efficiency of WSSe monolayers in splitting water for clean energy. (Ju *et al.* S4)

Another optimization technique involves sulfur vacancies. Sulfur vacancies can introduce defect states within the crystal lattice. Properly engineered vacancies can facilitate efficient charge separation, enhancing the mobility of charge carriers. For example, 2D rhombohedral ZnIn_2S_4 with rich sulfur vacancies has effective electron-hole separation efficiency which, coupled with its crystal phase, improves overall water splitting performance. In fact, the solar-to-hydrogen conversion efficiency of sulfur vacancy-enriched rhombohedral ZnIn_2S_4 reaches the highest reported efficiency for single-phase ZnIn_2S_4 , as found in *Sulfur Vacancy-Enriched Rhombohedral ZnIn_2S_4 Nanosheets for Highly Efficient Photocatalytic Overall Water Splitting under Visible Light Irradiation* by Haitong Jing, Gao Xu, and others. As seen in Fig 7, the photocurrent spikes of ZnIn_2S_4 -800 show that the holes gathered at the electrode/electrolyte interface cannot move to the electrolyte quickly. The correlation between

this and the surface states indicates that the sulfur vacancies and the crystal phase collaboratively boost the carrier concentration.

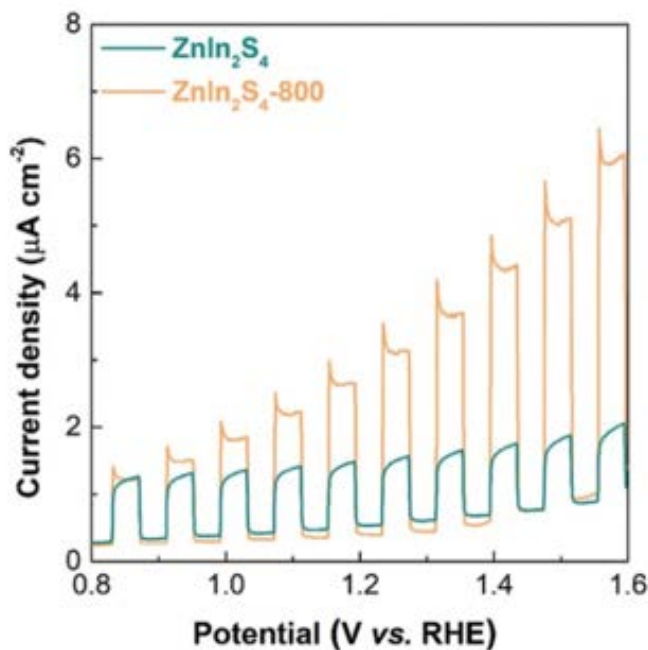


Fig 7: This figure shows spikes in photocurrent for ZnIn₂S₄-800, showcasing optimized carrier concentration through the collaboration of sulfur vacancies and crystal phase. This is crucial for improving the efficiency of water splitting, where more carriers mean better energy conversion. (Jing *et al.* 10192)

Finally, sulfur richness can tune the bandgap by influencing quantum confinement effects. Narrowing the bandgap improves PEC performance as it aids in the absorption of a broad spectrum of solar energy. Bandgap narrowing may be accomplished by integrating a donor-acceptor into the semiconductor. ~1.6–2.2 eV is the optimal band gap for effective PEC water splitting. Within this band gap range, the band edge location is precise, and the photo charge carrier mobility is increased. For example, in the work done by Torben Daeneke, Nripen Dahr, and colleagues, in *Surface Water Dependent Properties of Sulfur-Rich Molybdenum Sulfides: Electrolyteless Gas Phase Water Splitting*, sulfur rich MoS features a narrow band gap which shows high conductivity. This enables its outstanding performance as an electrocatalyst. Each of the materials presented above have their own merits when it comes to water splitting applications. However, considering the emphasis on photocurrent density and efficiency in photoelectrochemical water splitting, Sb₂Se₃ stands out as the most promising material. It demonstrates exceptional photocurrent density, attributed to well-ordered vertical nanowires of Sb₂Se₃ and the direct bandgap resulting from its layered structure. The anisotropic characteristics of Sb₂Se₃ also allow for directional control of reaction pathways, enhancing overall efficiency. While Pyrite NiS₂, NiSe, and CZTS-Ag₂S exhibit interesting properties, which could increase the efficacy of some aspect of the water splitting process, Sb₂Se₃'s superior photocurrent density

and efficient charge transport make it a robust candidate for optimizing catalytic activity in photoelectrochemical water splitting.

To optimize Sb_2Se_3 , sulfur richness stands out as the most promising optimization method in photoelectrochemical water splitting due to its ability to tune the bandgap and influence quantum confinement effects. The layered structure of Sb_2Se_3 , characterized by well-ordered vertical nanowires of Sb_2Se_3 , makes bandgap tuning through sulfur richness highly relevant, enabling the material to efficiently absorb a broad spectrum of solar energy. This method aligns with the emphasis on achieving high photocurrent density, a notable strength of Sb_2Se_3 , by enhancing the absorption coefficient. Additionally, sulfur vacancies, associated with this approach, introduce defect states that facilitate efficient charge separation, further contributing to enhanced charge carrier mobility. The chosen optimization strategy complements the inherent characteristics of Sb_2Se_3 , making sulfur richness the most suitable method to maximize the efficiency of the water splitting process.

While sulfur enriched Sb_2Se_3 remains the premier material and method combination for optimizing electrocatalysts in water splitting, it is worth acknowledging that alternative materials mentioned above, when subjected to methods tailored to their specific characteristics, can also pose competitive solutions.

For example, Pyrite NiS_2 , with its ability to transition from semiconductive to metallic characteristics through vanadium (V) displacement defects, suggests that optimizing charge carrier separation and mobility could significantly enhance its electrocatalytic activity for water splitting. Introducing sulfur vacancies can strategically induce defect states within the crystal lattice, creating favorable conditions for efficient charge separation. The defect-rich environment can facilitate the mobility of charge carriers, improving overall electrocatalytic performance. Sulfur vacancies may enhance the catalytic sites, promoting the oxygen evolution reaction (OER) efficiency crucial for water splitting. This optimization aligns well with Pyrite NiS_2 's unique electronic structure and metallic properties, aiming to enhance its electrocatalytic activity for efficient water splitting.

CZTS- Ag_2S , with its p-n heterostructure serving as a sensitizer for enhanced photocurrent response, could benefit significantly from the introduction of composite materials. Composite materials, formed by incorporating nanoparticles with desirable characteristics, can optimize the overall effectiveness of the CZTS- Ag_2S heterojunction catalyst. The addition of nanoparticles could enhance charge transport, boost light absorption, and facilitate efficient charge separation, thereby improving the photoelectrochemical (PEC) performance. By carefully selecting nanoparticles that complement the properties of CZTS- Ag_2S , such as those with suitable band alignments, the composite material can contribute to achieving a higher photocurrent density and overall efficiency in the water splitting process. This optimization strategy aligns with CZTS- Ag_2S heterostructure design, aiming to maximize its PEC activity through synergistic effects with composite materials.

Summatively, the choice of optimization techniques for semiconductor materials in photoelectrochemical water splitting depends on the unique characteristics of each material.

Tailoring the optimization methods to align with the material's inherent properties is crucial for achieving enhanced performance. For instance, sulfur richness emerges as a highly effective optimization technique for Sb_3Se_2 due to its ability to tune the bandgap and influence quantum confinement effects, complementing the layered structure and emphasizing the material's strength in achieving high photocurrent density. Similarly, for Pyrite NiS_2 , sulfur vacancies are deemed optimal as they capitalize on the material's transition from semiconductive to metallic states through vanadium displacement enhancing the charge carrier separation and mobility. On the other hand, composite materials are identified as a preferred optimization strategy for CZTS- Ag_2S , leveraging its p-n heterostructure to improve charge transport and light absorption. This tailored approach ensures that each material's specific characteristics are synergistically enhanced, providing a targeted and effective means to optimize their catalytic activity for photoelectrochemical water splitting.

5. Conclusions/Future Directions

Optimizing the performance of TMCs in water splitting rests significantly on tuning their surface characteristics. This imperative is exemplified through the strategic introduction of vacancies, composite materials, Janus particles, and sulfur-rich configurations. These surface engineering techniques play a pivotal role in enhancing the overall efficiency of TMCs by contributing to improved charge separation, heightened light absorption capabilities, and the tailoring of band structures. The synergistic impact of these modifications results in superior photocatalytic and photoelectrochemical activities. The thorough comprehension of these surface-tuning methods not only sheds light on the fundamental mechanisms governing TMC behavior but also lays a strong foundation for the advancement of their practical applications in the critical domain of water splitting.

Despite this strong foundation however, challenges still remain in the field of water splitting: first, the limited understanding of environmental factors' influences on the energetics and stability of semiconductors, as well as the properties of catalysts in photoelectrochemical water splitting, (Marwat et al. 12024) poses obstacles to the advancement of this crucial renewable energy technology. The optimization of water-splitting systems is inherently tied to the intricate interplay between semiconductor materials, solution environment, and catalysts. Without a comprehensive grasp of how factors like pH, solution composition, and ionic strength impact these components, researchers face challenges in developing efficient and stable systems.

The rectification of this knowledge gap is crucial for several reasons. Firstly, the efficiency of photoelectrochemical water splitting is directly correlated with the electrochemical behavior of semiconductors and catalysts. A nuanced understanding of how environmental factors influence these components is essential for tailoring materials and conditions to maximize performance. Without this knowledge, the full potential of PEC water splitting as a sustainable and viable method for hydrogen production remains unrealized. Secondly, the stability of the components over prolonged usage is a critical concern for practical applications. Incomplete knowledge of the impact of environmental variables can lead to accelerated degradation,

reducing the overall lifespan of water splitting systems. Addressing this limitation is imperative for the development of durable and economically viable technologies that can be implemented on a large scale. Finally, closing this knowledge gap is essential for guiding future research innovation in the field. A thorough understanding of the complex relationships between environmental factors and semiconductor-catalyst systems will pave the way for targeted improvements and the development of novel materials. This, in turn, will contribute to overcoming the current limitations and advancing the broader goal of harnessing solar energy for sustainable hydrogen production.

To address this knowledge gap, a series of systematic experiments can be designed. Firstly, experiments can be designed to investigate the influence of solution composition. This entails altering the composition of the electrolyte solution by introducing different ions or adjusting the concentrations of existing ones. The subsequent effects on semiconductor behavior and catalyst properties can then be analyzed. For example, the impact of pH variations on the semiconductor/s energetics and stability can be assessed by conducting PEC measurements under controlled pH conditions. This involves systematically varying the pH of the electrolyte solution and monitoring the resulting changes in the semiconductor's performance. Similarly, the role of ionic strength can be explored by varying the concentration of electrolytes in the solution. This is crucial as the presence and concentration of ions can significantly impact the electrochemical behavior of the semiconductor and catalyst.

These experiments collectively aim to elucidate the impact of pH, solution composition, and ionic strength, allowing researchers to contribute to valuable insights towards optimizing the performance and stability of semiconductors and catalysts in this critical renewable energy process. Not only will this facilitate the optimization of current systems but will also provide a foundation for the development of next-generation materials and methodologies, bringing us closer to a sustainable and efficient future for hydrogen production.

Another challenge is that the evolution of vacancies and defects in materials, particularly their impact on outstanding electrocatalytic activities during long-term electrolysis in water splitting, remains a widely unknown aspect in the field of renewable energy research (Liu et al. 2623). Vacancies and defects play a pivotal role in determining the catalytic performance of materials, influencing their electronic structure, reactivity, and stability. In the context of prolonged electrolysis for water splitting, the lack of understanding regarding the dynamic behavior of these defects poses a significant problem.

The electrocatalytic activities of materials can be highly dependent on the presence and distribution of vacancies and defects. Over extended periods of electrolysis, the evolution of these imperfections could lead to changes in the material's catalytic efficiency, potentially resulting in reduced performance or even degradation. This lack of knowledge poses a considerable obstacle to the development of durable and efficient water splitting technologies for large scale applications.

Addressing this issue requires a multifaceted research approach. One potential avenue is the development of in-situ characterization techniques that can monitor the evolution of

vacancies and defects in real-time during electrolysis. Advanced imaging and spectroscopic methods, such as in-situ transmission electron microscopy (TEM) or operando X-ray absorption spectroscopy, could provide insights into the structural changes occurring at the atomic level.

Additionally, controlled accelerated aging experiments can be designed to simulate long-term electrolysis conditions. By subjecting materials to extended electrochemical cycling under realistic operating conditions, researchers can observe and analyze how vacancies and defects evolve over time. This experimental approach, combined with thorough material characterization before and after aging, can offer valuable data on the stability and electrocatalytic performance of the materials.

Another avenue for research involves computational modeling and simulations to predict the evolution of vacancies and defects under various electrolysis conditions. Advanced computational techniques, such as density functional theory (DFT) calculations, can provide insights into the thermodynamics and kinetics of defect formation and migration. Combining these simulations with experimental data can contribute to revelations of the long-term behavior of electrocatalytic materials.

Furthermore, one additional strategy for increasing PEC efficiency is to develop a better co-catalyst. In smaller particles, the electro-kinetics dominate, resulting in increased electron-hole recombination. Larger particles exhibit band bending characteristics, allowing for better charge extraction at the electrode-electrolyte interface. Thus, bigger cocatalysts are preferred for the improved PEC performance.

Alternative options include optimizing the configuration of a PEC cell. Optimizing the arrangement of components within the cell would maximize light absorption, facilitate efficient charge separation, and improve the overall performance of the system. Utilizing tandem cell structures or multi-junction cells with semiconductor layers responsive to distinct wavelengths enables a more comprehensive absorption of the solar spectrum, reducing energy loss and enhancing the overall photon-to-current conversion efficiency. Designing the photoanode and photocathode configuration carefully, along with selecting appropriate electrolytes and integrating effective catalysts, contributes to minimizing overpotentials and improving the kinetics of the oxygen and hydrogen evolution reactions. Additionally, the spatial separation of these reactions within the cell mitigates energy losses associated with simultaneous processes.

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Understanding COVID-19's Impact on Commercial Real Estate by Raghav Gupta

Abstract

This research paper explores the impact of the COVID-19 pandemic on commercial real estate in the United States, analyzing its impact on societal dynamics. The study explores several industries including retail, and office, and note how these industries have adapted. Statistical data analytics before, during, and after the pandemic were used to understand the extent of the impact. By using this data, we make predictions of what the future holds in each industry.

Furthermore, this study examines overall trends in specific cities to develop an understanding of how consumer behavior has changed and what businesses are doing to adapt to these changes.

Based on the evidence, as the work-from-home life culture continues to spread through various industries, office vacancy rates will continue to increase as more businesses transition towards remote conditions. The United States is at an all time high in vacancy rates with no sign of decreasing. Industries like IT have led this movement, while others aren't far behind. Moreover, the retail industry will continue to expand its digital capabilities as people prefer shopping from the convenience of their homes. Businesses unable to adapt online will have difficulty competing with other businesses.

Introduction

When the COVID-19 pandemic began in March 2020, all offices and businesses were forced to shut down leading to alternative means of working, which had significant effects on office vacancy levels throughout the nation. This led to the spread of a new remote work practices where workers could work from their homes in a more comfortable environment. As workers shift towards this environment companies have lost the need for office accommodation. (Vise) This has caused a significant decline in the demand for office spaces throughout the United States. Working from home proved to be much easier for employees as it allowed them to have flexible hours, eliminated their daily commute, and gave them more time for other activities. Prior to COVID, 5% of workers worked remotely. This increased to 24% between April and December of 2020, comprising 35.5 million people (Coate). This shift in work culture has changed societal norms that have existed for few a hundred years, normalizing remote work environments. This study concludes that based on workers' desire to maintain work-from-home practices, companies will continue to have a decrease in demand for office businesses to adopt more flexible and remote work arrangements.

Moreover, the pandemic has had an unprecedented impact on the retail sector, as it has disrupted the supply chain, labor force, and consumer behavior. During the pandemic, physical vendors were forced to shut down, causing a sudden shift towards e-commerce. This transformed the way people shopped because it allowed them to acquire all their basic desires and needs at their doorstep. Even groceries were made available, making once unthinkable feat possible.

From 2019 to 2020, online grocery shopping saw a 233% increase and reached the highest level in December 2022 with sales at \$7.6 billion (Ozbun).

Background

To understand how the pandemic has impacted the commercial real estate market, we will examine several cities that facilitated the development of major industries. It is important to understand this is the overall trend, and some cities have been affected more than others, particularly cities that were influenced by the ever-growing IT industry. San Francisco, known for its vibrant tech and startup scene, has experienced a significant impact on its commercial real estate market. Since office spaces had become less used over the course of the pandemic it became beneficial for companies to end the lease for their office buildings, in order to save money. Additionally, remote work conditions have made it easier for companies to hire employees with specialized skills in different places. This has helped to increase productivity as in-person-only companies are confined to the skills of the people in a specific region. Another major city, not renowned for its IT status, but rather for its healthcare and financial industries is New York City. New York is the United States's largest city, with a population of approximately 8.3 million people. However, the effects of the pandemic were rather severe in New York, which did not favor remote work. As working from home removed the geographical barrier on workers, many companies began outsourcing their work to various countries. This has led many companies to outsource jobs. An economist from Stanford University, Nicholas Bloom, estimates 10-20% of US service jobs like software developers as it more affordable (Tsipursky).

Data & Results

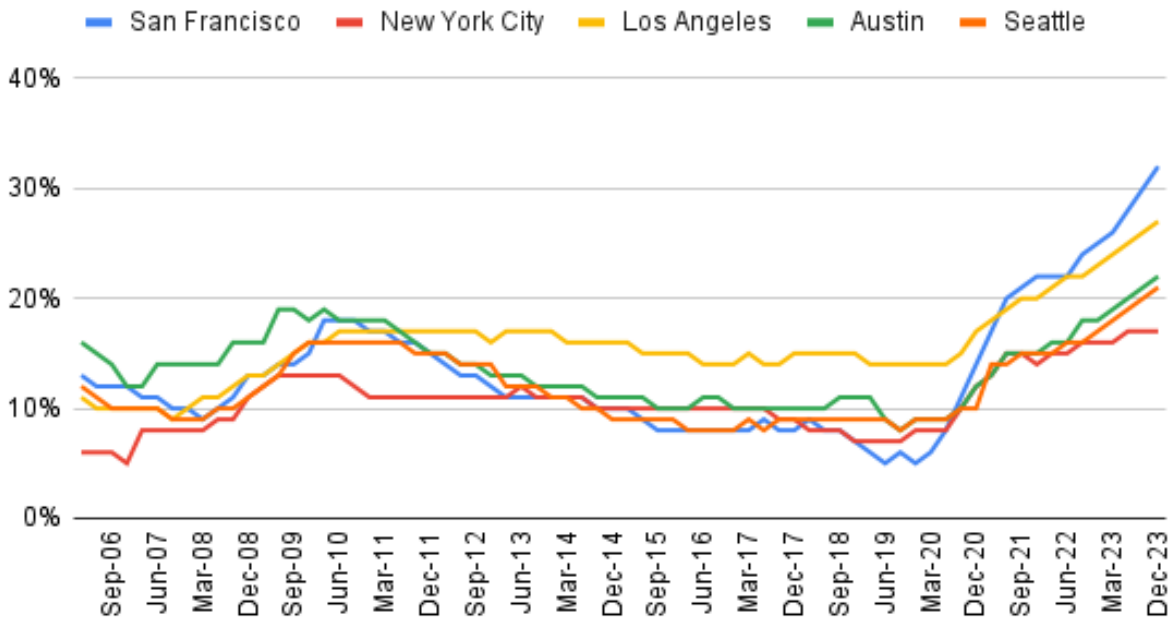
Vacancy rates increased from 12% in the 4th quarter of 2017 before the pandemic to 17% the 4th quarter of 2023, reaching an all time high in some places across the nation (Statista). During the first quarter of 2024, San Francisco reported a 36.6% office vacancy rate, one of the largest in the nation (Rogers). Studies have shown that workers have opted to move to greener, environmentally friendly communities in suburban areas as they were able to operate remotely. This trend has remained prominent throughout the country as over 2 million Americans have moved from urban metropolitans to smaller communities from 2020 to 2022 (Vise). In major cities consisting of over 10,000 people per square mile, moving rates increased by 17% (Henderson). The IT industry has emerged as the leading sector of remote work as most of this work can be performed digitally remotely. Other industries including marketing and finance are not far behind, as they adapt to remote working conditions by integrating digital platforms. Silicon Valley, known for being home to global enterprises Google, Apple, and Facebook, has continued to increase vacancy rates reaching 17%. Additionally, it has reached a record 7.6 million square feet in available office space as compared to 2.7 million square feet in 2019 (Bartholomew). Businesses are developing hybrid work models to have a blend of in-person and virtual work environments. Meanwhile, New York, reported a 19.2% vacancy rate, although down from its peak, it is still significantly more than its pre-pandemic levels at around 9.9%

(Osgood). Ultimately, the cause of NYC's low rental vacancy rate and high office vacancy rate is the lack of supply for an ever-growing pool of demand from companies, as the once dramatic demand for office space is no longer prevalent. As the pandemic's spread slowed, people began to resume their daily lives and needed places to live near office spaces again, due to the slowly decreasing amount of remote work. In the future, the rental vacancy rate is expected to steadily increase, due to an influx of citizens moving away from urban cities. This may also cause rent prices in NYC to increase dramatically. Additionally, following the increase in job opportunities after the pandemic, the unemployment rate has also decreased from around 21% in May 2020 to 5.1% in February 2024 (YCharts).

The tech industry has been the first to adapt to this remote working condition as the work-from-home trend continues. As much of their work was already primarily digital, tech hubs like San Francisco and Seattle have some of the highest office vacancy rates, while other cities aren't far behind. This is evident as the national average has increased consistently from 16.8% in prepandemic times to over 19.6%(Moody Analytics) . Industries like marketing and finance are taking a bit longer to adapt.

During the years after the pandemic, the retail industry saw consistent overall growth as e-commerce surged by 43% in 2020, reaching \$815.4 billion. Following the transition to digital and contactless payment practices, retail employment suffered significantly. Many stores began integrating self-checkout forms of payment, causing employment projections for cashiers(approximately 17% of the retail workforce) to lose 7% of their workforce by 2029 (NLC 100). The future of the retail market will continue to be influenced by online consumerism as online retail continues to become more effective and convenient for consumers. Many businesses unable to adapt to provide goods and services digitally were forced into bankruptcy and closure, including a record 12,200 store closures in 2020 (Wahba). A 2021 report shows that 71% of small-medium businesses survived the pandemic by going digital, providing a strong indication that businesses will have to integrate digital alternatives to thrive. (Bensley)

Vacancy Rates



Credit: Sf.gov

Figure 1 Office vacancy rates in major cities

Figure 1 illustrates the office spaces vacancy rates in five cities known for their technology employment. Up until March 2020, right before the beginning of the pandemic, the vacancy rates maintained a consistent downward trend, only spiking during the 2008 financial crisis and its subsequent years. The vacancy rate increased from March 2020 to the present, due to the pandemic relocating a majority of workers remotely from their homes. Remote work was beneficial to the IT industry, as companies no longer had to hold their office spaces, and many leases were terminated. The culmination of the pandemic's effects led to the upward trend depicted in the last four years in Figure 1. The discrepancy between these major cities is still significant, especially between San Francisco and New York. San Francisco is a haven for the technology industry, and the vacancy rate dramatically increased after the pandemic began, starting from an all-time low of ~6% and increasing to 32% at its peak. Los Angeles sits right below San Francisco but maintained a high vacancy rate throughout the last two decades due to its abundance of complexes that are largely left vacant.



Source CBRE, San Francisco average cost per sq m
 Figure 2, Average cost of business rental space in San Francisco

Figure 2 illustrates the average price per square foot of rental space in San Francisco, one of the world’s largest IT hubs. Each of the lines on the graph depicts a different level of luxury, with Class A being the most luxurious and Class C the least luxurious. The graph shows a steady decline in all three classes due to the decrease in the number of people living in the city. As the pandemic ran its course, many people moved from urban centers to other cities to reduce their cost of living while earning a high salary from a well-known IT company, like Google or Amazon. Figure 1 and Figure 2 demonstrate an inverse relationship over time, in that as the vacancy rate increases, the price per square foot decreases. As shown in Figure 2, all 3 classes plateau at an all-time high right at the cusp of the pandemic, before dropping. Class C real estate dropped the most, as many companies would rather have no office space than a less luxurious one. This cycle continues up to the present day, as the relationship between the two is similar because of a feedback cycle. As the vacancy rate increases, the price per square foot decreases, thus causing the vacancy rate to go up again, perpetuating the cycle. However, as the pandemic declines, the cycle will abate and ultimately cease because vacancy rates stabilize, as people begin to go back to work on-site.

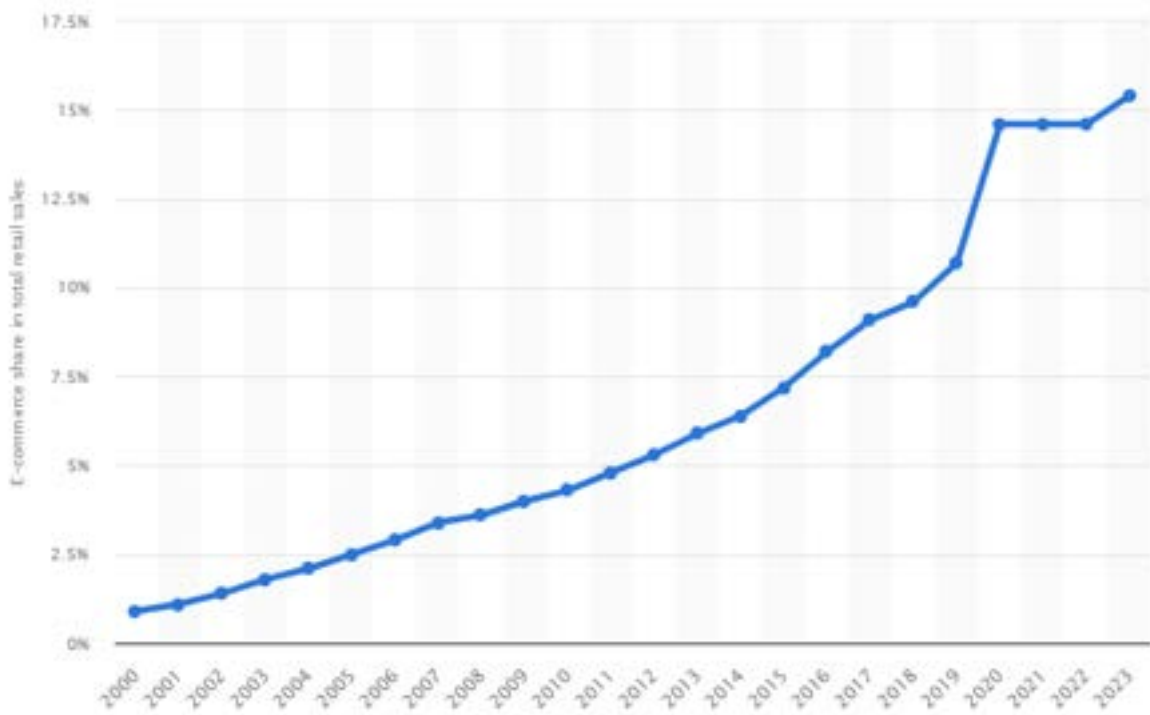


Figure 3 US e-commerce share in retail sales

Figure 3 shows a consistent increase in E-commerce share of retail sales. As lockdowns and social distancing measures were enforced, consumers shifted to online platforms. This led to an increase in e-commerce transactions. In the years before 2020, there was a dramatic increase in retail activity. The amount of activity increased from 10.7% to 14.6%, marking a 34.4% increase. Meanwhile from 2000 to 2018, there is about a 13.5% increasing showcasing the profound impact of the pandemic. When the pandemic began, there was a clear exponential increase in the online retail markets as the growth rate was substantially higher. This trend is constantly increasing till suggesting that it will continue to grow in the future.

Conclusion

The COVID-19 pandemic's impact on the commercial real estate industry has remained unmistakable as it has altered cultural norms. It has introduced us to a new form of work culture that has drastic effects on office supply/demand, and the way retailers provide products. The immediate lockdowns in March 2020 forced businesses to adapt to new forms of work, involving workers operating out of their homes. Workers enjoyed this new lifestyle, allowing them to work out of the convenience of their homes and avoid daily commutes. This led many to escape the chaotic metropolitans for greener suburbs. However, this caused many offices to become vacant, in a continued increasing trend. The IT industry led this trend as they were the first to adapt, as evident through the large vacancy rates throughout Silicon Valley. Other industries aren't far behind and are continuing to adapt, causing a decrease in office space demand. As office spaces

are able to save on rental costs and hire employees in various cities, we can expect to see an increase in vacancy rates as businesses continue to adapt causing cities to become increasingly empty. The national vacancy rate in the United States prior to the pandemic was roughly 12%. However, according to a study conducted by Cushman & Wakefield, vacancy rates are expected to increase to 18% by 2030, a figure about 1.3 times greater than its pre-pandemic turnout. With an increase in vacancy rate across the nation, office spaces are going to become increasingly irrelevant as technology becomes the kingpin of facilitating company interactions.

Additionally, the pandemic has transformed how consumers shop. As many retail stores were forced to shut down, businesses shifted towards e-commerce-based platforms enabling customers to shop from the convenience of their computer. This trend continued rapidly and spread across various industries, including groceries. Many businesses that struggled to integrate digital alternatives were forced into closure. As e-commerce continued to become the preferred option, many retail stores shut down and focused on digital business. For businesses to thrive in the future, they will need to focus on providing their products digitally to allow them to reach larger markets.

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Men-in-Machines: The Importance of the Individual By Alexander Sabat

Through the motif of men-in-machines, Ellison critiques the modern world, highlighting institutions such as the educational system, the factory, and the Brotherhood that dehumanize individuals, suppress their individuality, and force them to conform to oppressive expectations in exchange for educational, economic, or social advancement. The depiction of people as cogs in educational, economic, and political machines suggests that to progress in modern society, one must surrender autonomy and reshape oneself to predefined roles. However, despite being overlooked and exploited by these oppressive systems, these marginalized individuals are the true foundation that keeps these institutions running, highlighting their irreplaceable importance in society.

In *The Invisible Man*, the “battle royal” scene illustrates the educational system’s role as a machine that forces marginalized individuals to endure humiliation and subordination, molding them to fit predefined roles set by white society. Before giving his speech to his town’s white leaders, the narrator must participate in a degrading blindfolded boxing match with other black boys for entertainment. Blindfolded, he “had no dignity,” “stumb[ing] about like a baby or a drunken man” (22). Stripped of autonomy, he becomes a mere source of amusement. The narrator is then forced to collect coins from an electrified rug, a metaphor for the obstacles black people face to gain opportunities. Only after enduring humiliation and conforming to the white men’s standards in his speech is the narrator rewarded with a college scholarship. This scene demonstrates how the college operates as a machine that rewards submission and conformity; to gain access, he must endure humiliation and subordination to white men. During his speech, the narrator mistakenly says “social equality” instead of “social responsibility,” revealing his subconscious belief that he should not continue as a cog in this machine. Despite this Freudian slip, he remains unaware of its implications at the time and continues to conform. This scene depicts the educational machine that seeks to suppress individuality, reflecting how marginalized individuals must surrender their autonomy and accept a subservient role to gain access to opportunities.

The Liberty Paints Factory serves as a dehumanizing institution; the very nature of the factory suppresses individuality, reducing individuals to cogs in machines, while it also physically attempts to remove the narrator’s individuality. After being expelled from the college, the narrator finds employment at the Liberty Paints Factory. After initially being assigned to mix paint, after making a mistake he is eventually sent downstairs to work under Mr. Brockway, a black worker. Despite having one of the most important roles in the factory—creating the Optic White paint—Brockway is underestimated by the white factory owners who fail to recognize their reliance on his expertise. By keeping Brockway’s work out of sight in the basement, the factory can overlook the importance of skilled laborers who provide essential work for their company. Brockway describes himself as “the machine inside the machine,” as he creates the paint, not the machines themselves (217). The factory employs disposable, interchangeable workers to maximize profit while overlooking the importance and expertise of workers such as Brockway

who deserve credit for the company's success. This is further symbolized in the mixing process of the "Optic White" paint, where black droplets disappear to create the whitest paint, which is then applied to white products, serving as a metaphor for how the company's success relies on hidden labor.

The factory's dehumanizing treatment becomes more evident when the narrator is treated after an explosion in the basement. The narrator is treated like a malfunctioning part that needs to be fixed before returning to the machine. The factory gives him electroshock therapy without his consent, aiming to erase his individuality and make him compliant. The use of electroshock therapy shows the extremes the factory would go for economic success, disregarding human identity and autonomy for economic efficiency. After the narrator recovers, he is quickly disposed of as he is easily replaceable by another worker. This inhumane treatment displays the factory's view of workers as interchangeable components of a larger machine, stripping their identity and humanity. Through the process of mixing paint and Brockway's expertise, Ellison shows that these marginalized workers at the factory who are reduced to mere replaceable components are the backbone that keeps the system running. By marginalizing and keeping these essential individuals out of view, the factory shifts the power to emphasize the authority of the white men in power, reinforcing the hierarchal structure of an indispensable upper management and interchangeable workforce. Keeping these crucial workers behind the scenes prevents them from gaining the recognition needed to challenge the power dynamic, allowing for maximum profit and power for the leaders in charge of the institution.

The Brotherhood functions as a political machine that is not only anti-individualistic in its nature, but it prioritizes its agenda over the value of individuals, using the narrator like a malleable part and molding him to fit their pre-defined role. Unlike the factory, which fails to recognize Brockway's significance, the Brotherhood understands the narrator's influence and potential and manipulates him to serve their agenda, suppressing his individuality whenever he deviates from their political goals. Throughout the narrator's time in the Brotherhood, whenever he presents his own ideas or expresses individuality, he is immediately criticized and silenced. He is "not hired to think," but to be a puppet for the Brotherhood's political agenda (469). During his first speech with the Brotherhood, when he mentions how he has "become more human," they dismiss this expression of humanity as "dangerous" and "incorrect," sending him to Brother Hambro to be trained in their ideals (346, 349). When the narrator is interviewed for an article, Brother Wrestrum accuses him of self-promotion, leading to his removal from the Harlem movement because personal gain is seen as a threat to the institution's ideals. The Brotherhood fears the narrator's influence over Harlem and the possibility of him now deviating from their political ideals, so they send him down to the Women Question away from the influenced Harlem. Additionally, when the narrator hosts a funeral for Brother Clifton under his "personal responsibility," despite attracting a large crowd and swaying the audience, the Brotherhood belittles him for acting independently. They denounce him even when his intentions are to just honor a fellow member. The Brotherhood's manipulation and exploitation of the

narrator reinforces the men-in-machines motif, as the Brotherhood attempts to mold the narrator to fit their oppressive expectations, disregarding him being the foundation of their success.

The educational system, Liberty Paints Factory, and the Brotherhood all serve as machines that marginalize individuals into mere tools to maintain power, embodying the recurring motif of men-in-machines as Ellison critiques the oppressive nature of modernity itself. The “battle royal” scene illustrates that to gain educational opportunities, the narrator is stripped of his dignity and forced to conform to an oppressive racial hierarchy. The Liberty Paints Factory views its workers as interchangeable parts, despite some individuals, such as Mr. Brockway, having a vital role in the company’s success. The Brotherhood manipulates the narrator to fit its political agenda, suppressing his individuality. However, not only does Ellison critique the dehumanizing nature of these institutions, but he also emphasizes their reliance on the individuals that they utilize. Ellison suggests that these institutions would collapse without the marginalized individuals they exploit, ultimately highlighting the importance of the overlooked individuals that sustain these institutions.

Impact of Consumer's Prior Knowledge on Information-Seeking and Decision-Making in Product Selection By Rui Ma

Abstract

This study conducted a Qualtrics survey with two between-subject conditions to examine the impact of the consumer's prior knowledge on information-seeking behaviors during product selection. Participants were randomly assigned to either a "prior knowledge" condition, receiving information about average product prices, or a "no prior knowledge" condition without such information. Findings reveal that individuals with prior knowledge tend to engage in more extensive information searches when faced with contradictory data. In contrast, those without prior knowledge prefer direct product choices. This insight has significant implications for marketers seeking to align consumer knowledge with product attributes to influence consumer behavior and perceptions.

The structure of this paper

The provided paragraph delves into the extensive research conducted on the influence of prior knowledge and information search behavior in consumer decision-making. It cites specific studies by Grewal and Tansuhaj (2001) and Bettman and Sujan (1987) that have explored the interplay between prior knowledge levels and consumer behavior. These studies have provided valuable insights into how prior knowledge affects consumers' information search and decision-making processes. However, it also highlights the need for further investigation into situations where prior knowledge significantly deviates from the actual circumstances and how this variance influences consumer choices. The paragraph underscores the potential benefits of such research for businesses, marketers, and researchers, including improved marketing strategies, enhanced product development, and personalized experiences. It concludes by emphasizing the significance of studying consumer information search behavior and prior knowledge in adapting marketing strategies and enhancing the overall consumer experience.

Introduction

Numerous studies have explored prior knowledge and non-prior knowledge in different areas. For example, a study by Grewal and Tansuhaj (2001) investigated the impact of prior knowledge on consumer information search and found that individuals with higher levels of prior knowledge are more likely to engage in extensive information search, as they seek to enhance their understanding and make informed decisions. Conversely, individuals with lower prior knowledge may rely on limited information or social cues to purchase.

Bettman and Sujan (1987) conducted a study investigating the influence of prior knowledge and expertise on consumer decision-making. The research suggested that individuals with more prior knowledge tend to engage in more focused and systematic information search. In comparison, those with less prior knowledge may exhibit more heuristic decision-making, relying on simple heuristics or shortcuts.

This paper will explore the impact of prior knowledge on consumer decision-making processes, specifically when the knowledge differs significantly from the actual situation. By examining how individuals' decisions are influenced in such scenarios, we can gain valuable insights into the role of prior knowledge in shaping consumer behavior.

These studies provide insights into the information-seeking behavior of consumers with different levels of prior knowledge, But may there not be a definitive article on the specific topic of research on understanding how prior knowledge affects consumer information search and decision-making processes without prior research as evidence. So this paper is going to introduce how prior knowledge affects people's decisions when the prior knowledge is very different from the real situation and how this affects people's decisions.

Researching information search behavior and prior knowledge in the context of consumer behavior can yield several valuable benefits for businesses, marketers, and researchers.

Hypothesis

Knowledgeable people will find more information about one product and the less knowledgeable people about one product will directly and aren't going to search for more information.

Advantage of high prior knowledge

According to Alba and Hutchinson (1987), cognitive science offers numerous examples of the advantages that high prior knowledge (PK) has on learning.

Experts use more automatic mental processes than novices do (Larkin et al. 1980; Shiffrin and Schneider 1977). Chi, Glaser, and Rees (1982) claim that automaticity often speeds up a process without compromising the caliber of the output. This could free up resources for learning new information and other cognitive processes.

Furthermore, specialists tend to classify information at sublevels more often than novices, and so may be more sensitive to subtle perceptual cues that distinguish distinct members of a category (Johnson and Mervis 1997). Experts can identify issues more quickly and look for memories less frequently than novices because of the abstract schemata that experts can generate as a result of the intricate structure of PK (Chi et al. 1982; Prerau, Adler, and Gunderson 1992). Novices process information more data-driven. Furthermore, more intelligent customers could seek out further information before addressing difficulties because they can identify relevant information (Johnson and Russo 1984; Punj and Staelin 1983), ask perceptive inquiries (Miyake and Norman 1979), and are aware of existing attributes (Brucks 1985).

Consumers with knowledge may seek out experts' help, as opposed to novices who take in information more data-driven (Chi et al., 1982; Lamberti & Newsome, 1989). Since they are aware of existing characteristics (Brucks, 1985), they can make insightful inquiries (Miyake & Norman, 1979), and can identify pertinent information (Johnson & Russo, 1984; Punj & Staelin, 1983), better-informed customers may also seek out more information before solving problems. There are some benefits of having Prior Knowledge for consumers are summarized here.

When a person has Prior Knowledge they process information in a positive way rather than passively accepting the information given to them. The literature on the effects of prior knowledge provides insights into these processing preferences. It shows that consumers who possess a great deal of domain knowledge feel a sense of urgency to reach their goals (Lewandowsky and Kirsner 2000). As a result, they tend to follow well-trod and procedural solution paths (Spence and Brucks 1997; Wiley 1998), search for information selectively (Nettman and Park 1980; Schraagen and Leijenhorst 2001), and prioritize information that is central to their objective (Lewandowsky and Kirsner 2000). The correspondence between prior knowledge and processing strategies can also result from a message presentation at the appropriate level of construal, which refers to the abstract or concrete representation of the information (Trope and Liberman 2003; Trope, Liberman, and Wakslak 2007). Consumers with extensive knowledge are more aware of what their purchase objectives are they are less likely to have their minds changed by the seller at the time of purchase and will choose the option that they believe is more suitable for them. They are open to more advanced or abstract explanations even when they are in the process of learning about the product. People with prior knowledge are usually more fluid and positive when dealing with problems.

And people with prior knowledge in the presence of the Internet can better find products that suit them at the right price.

Disadvantage of the high prior knowledge

According to Punj and Staelin (1983), consumers with higher prior knowledge (PK) may experience overconfidence, the "feeling-of-knowing" (FOK) phenomenon, and the application of inappropriate inference rules during either encoding or retrieval (Punj & Staelin, 1983).

Overconfidence is a pervasive tendency that causes people to believe they know more than they do (Fischoff et al., 1977). According to Oskamp (1965), decision-makers confidence in their performance rises as the amount of available information does, but actual performance accuracy does not.

It is anticipated that overconfidence prevents information search that is driven by the need to satisfy curiosity (Menon & Soman, 1999) or a desire to lessen knowledge uncertainty (Alba & Hutchinson, 2000). As demonstrated by Bandura's (1977) research on self-efficacy, confidence in one's ability to learn can stimulate learning attempts, but confidence in one's prior knowledge might impede such efforts. Consumers who are more informed may absorb information less thoroughly than is possible and learn less than those who believe they are less knowledgeable if they have an erroneous belief that new product information will be redundant with what they already know.

The researcher will set up a questionnaire to investigate as the main method to obtain data to support the researcher's hypothesis.

Advantages of no prior knowledge

Having no prior knowledge can offer numerous advantages in various aspects of life. One

advantage of approaching a situation or topic with no prior knowledge is the opportunity for unbiased exploration and learning. Without any preconceived notions or biases, individuals can engage in a more objective and open-minded investigation, leading to a deeper understanding of the subject matter (Smith, 2019). Furthermore, having no prior knowledge allows individuals to develop critical thinking skills and the ability to question assumptions. Instead of relying on existing information or beliefs, they are encouraged to think independently and consider multiple perspectives (Jones et al., 2018). This can foster intellectual growth and lead to the development of innovative ideas and solutions.

Another advantage of not having prior knowledge is the potential for enhanced creativity. When individuals are not constrained by established norms or conventions, they can think outside the box and explore unconventional ideas. This freedom allows for innovative thinking and the development of groundbreaking concepts (Johnson, 2020). Similarly, without any preconceived notions, individuals may be more inclined to take risks and experiment with different approaches or strategies. This willingness to try new things can lead to breakthroughs and advancements in various fields (Brown & Miller, 2017).

Additionally, having no prior knowledge can ignite a sense of curiosity and wonder. When individuals are faced with new information, they are more likely to be engaged and motivated to learn (Thomas, 2016). This curiosity drives exploration and a desire to seek answers and knowledge. As a result, individuals may become more self-directed learners, actively seeking out information and finding joy in the process of discovery (Robinson, 2009). In conclusion, the absence of prior knowledge offers several advantages. It enables unbiased exploration and learning, promotes critical thinking and independence, enhances creativity, ignites curiosity, and fosters humility and receptiveness. Embracing the opportunity to approach new situations with no prior knowledge can lead to personal and intellectual growth, innovation, and a deeper understanding of the world.

Disadvantage of having no prior knowledge

Without any prior knowledge, individuals may struggle to understand and interpret new information effectively. According to a study by Bransford and Johnson (1972), prior knowledge plays a crucial role in comprehending and assimilating new information. When one lacks prior knowledge, they may find it challenging to make connections or draw meaningful conclusions from the information at hand. This can impede the learning process and limit their ability to acquire new knowledge.

Secondly, the absence of prior knowledge can hinder critical thinking and problem-solving skills. According to Mayer (2004), prior knowledge acts as a mental scaffold that aids in problem-solving activities. It provides individuals with a framework to approach new problems and find solutions. Without this scaffold, individuals may struggle to think critically or generate effective problem-solving strategies, ultimately hindering their ability to overcome challenges and achieve success.

Furthermore, without prior knowledge, individuals may be more susceptible to making

uninformed decisions or being misled by others. Prior knowledge allows individuals to discern credible information from misinformation or propaganda. The lack of prior knowledge can make individuals vulnerable to manipulation and exploitation. In today's era of information overload, having no prior knowledge can leave individuals at a disadvantage in distinguishing between accurate and unreliable sources, potentially leading to poor decision-making and detrimental outcomes.

Research by Meena (2018) shows that people develop preferences for certain products or services at a young age due to the numerous commercial cues that influence their decisions. Promotion is currently one of the most effective ways of influencing consumer perceptions and decisions to buy (Khan et al., 2019) Advertising has a powerful ability to persuade and influence people, even benign advertisements can change customer behavior and influence their desire to buy. And if consumers do not have prior knowledge this influence will become even greater, leading consumers to engage in impulsive and irrational consumer behavior. In conclusion, the absence of prior knowledge can limit understanding, hinder critical thinking and problem-solving abilities, and make individuals more susceptible to misinformation. Therefore, it is crucial to acknowledge the importance of prior knowledge in various aspects of life and actively seek opportunities to acquire and build upon it.

Methodology

The researcher designed a Qualtrics survey. In condition 1, which the researcher referred to as the prior knowledge condition, is where people are given information about the average price of the products; whereas in condition 2, which the researcher referred to as no prior knowledge condition, people do not learn about the average price of the product. That is the only difference between the two conditions.

My questionnaire has two sections, each section has two main questions and three questions about age, name, and gender. Respondents must complete one question before they can answer the following question and cannot change previous answers or skip questions. For the accuracy of the survey, we have the same options for each of the first part of the two sections and the same options for the second question of each of the two sections, the only difference is that there is no information provided. Each investigator was randomly assigned a different question, neither the respondent nor the investigator knew what the assigned question was so that the variables could be better controlled and the experiment could be more accurate. In the first part of the experiment, we investigated consumer choice by providing the average market price and not providing the average market price. In the first part of the survey, the correct and incorrect average market prices were given, and according to my hypothesis, only people with high prior knowledge will conduct a new search when the product information does not match their knowledge, rather than choosing to buy the product directly. When consumers realize that their knowledge matches the product, they will choose the product that matches the information more, so for this part, we modeled people with high prior knowledge.

In the second part of the questionnaire, we do not give any market information, so the

people who do the survey are simulating people who do not have high prior knowledge of the consumption process, they can only make choices through their preferences, and they usually make choices directly instead of searching for more information. In this part of the survey, we simulate people without prior knowledge.

This is the introduction of the whole questionnaire.

A total of 285 people participated in this survey. The group that provided accurate information was named in-line and the group that provided incorrect information was named out-line. The second part of the questionnaire was named according to the naming scheme of the first part of the questionnaire. According to the survey data, in the section with high prior knowledge: if the average market price is in line with the reality, consumers who have this information will choose to buy items that are cheaper around the average price. However, when the average market price is not in line with reality, consumers with this information are more likely to choose the "search more" option. Even though most people still choose the product directly, the number of people who chose this option increased significantly from the previous question, from 15 to 27. The second part of the question did not give any information about the product, so the option "search for more" did not change significantly between the two questions, with only 16 people choosing to consume more in the first question and only 14 people choosing this option in the second question. This data shows that there is no significant change in consumers' choice behavior compared to the first part of the question and that they choose according to their own subjective will, without any basis. (The kinds of experiments that are chosen are not of interest to everyone, so people may be using their subjective ideas to choose things in addition to the information they're given.)

Results and findings

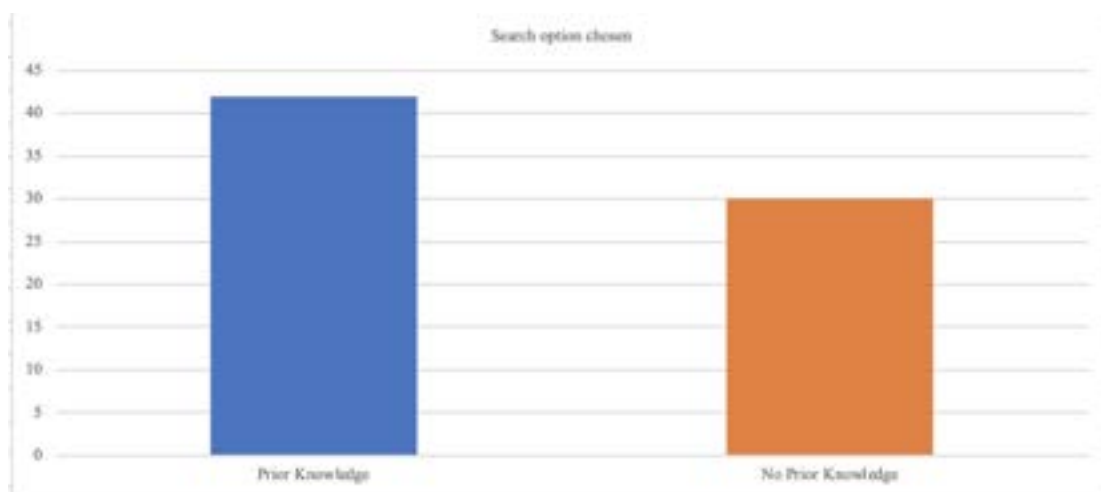


Figure 1. Results of search options (The original data from the researcher's study.)

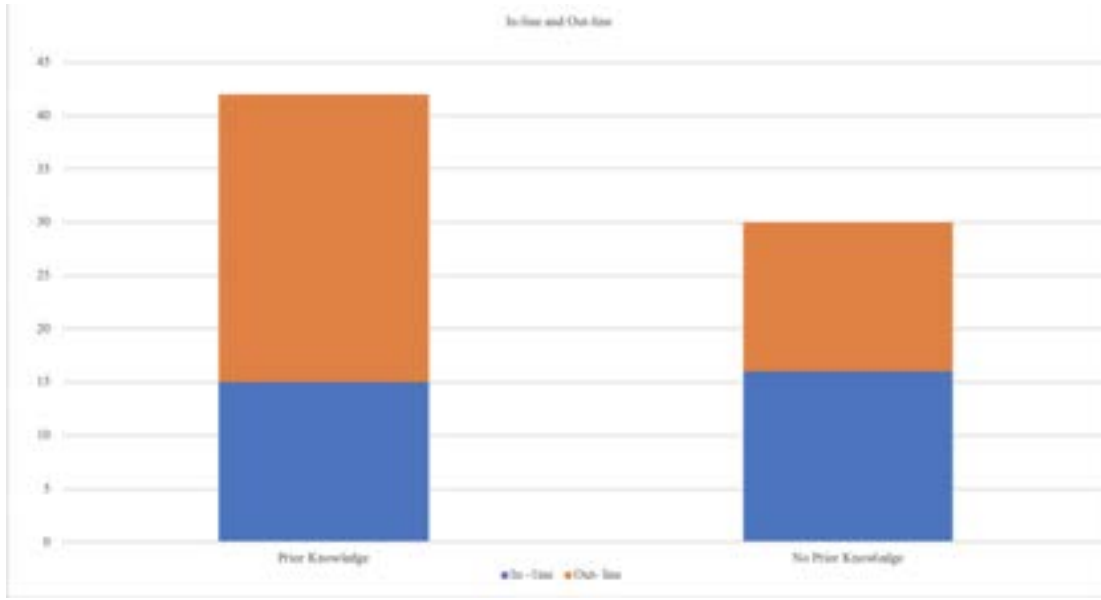


Figure 2. In-line(provided accurate information)and Out-line(provided incorrect information)
(The original data from the researcher's study.)

Based on Figure 1 we can see that this experiment is divided into two groups. One group is the prior knowledge group and the other group is the no prior knowledge group.

The number of times people chose the search option

-Prior knowledge group (total) 42

-No a priori knowledge group (total) 30

Figure 2 supports the hypothesis that people with a priori knowledge search for more options than people without a priori knowledge.

The consistency of the a priori group implies that they do not agree on the average price of video games. This reflects a large gap between what they see as the price of the product and the price of the product. Therefore, it can also be seen based on the icon that the number of people (out-line) who chose "continue to choose" was significantly higher than the first option. The a priori group, on the other hand, did not have this information, but the product was the same, so there was no significant change in their choice because whichever choice they made was based on their subjective will.

This means that if the a priori group exceeds the price and the first product is above the average price, they will look for more products until they find the right price or a price between the average prices they know. However, if people without prior knowledge do not search because they do not know what product is better or what the average price of a product is, they will buy the product they see or hear about for the first time. This is shown in Figure 2 above.

Based on this data, it is possible to support the hypothesis that people who gain more knowledge will find more information about a product, whereas people who know less about a product will just buy it without searching for more information.

Discussion

These are the benefits for people who know Prior knowledge and No a priori knowledge Here are some of the main advantages:

Better Marketing Strategies: Marketers can more accurately target advertising

Improved Product Development: Analyzing consumers' information searches can reveal what details people consider important when evaluating goods and services. This information can help companies design products that better meet the unique requirements and tastes of their target markets, thereby guiding the development of new products.

Producing Relevant Materials Research on information search patterns and past performance can help companies produce content that appeals to customers. By identifying information gaps in consumer knowledge and information that consumers are already trying to fill, companies can create content that informs, engages, and influences purchasing decisions.

Customized Experiences: Marketing strategies can be developed with the help of customer behavioral research. Companies can use past purchases and information-seeking trends to provide customized product recommendations, offers, and creatives that match customer preferences.

Effective Communication Skills: Researchers can identify words, expressions, and communication patterns that resonate with specific target groups. As a result, organizations are better able to communicate their value propositions and increase customer engagement and conversion rates.

Information Overload: By gaining a comprehensive understanding of how consumers process and organize information, companies can avoid bombarding potential customers with too much information. Instead, they can provide brief but necessary information to help customers make decisions without overburdening them psychologically, leading to increased satisfaction and loyalty. Customers are more likely to be satisfied with their purchase if a business provides relevant and useful information when requested. This satisfying experience increases customer loyalty and advocacy. **Advantage** Companies that strive to understand search patterns and historical data relevant to their customers can gain a competitive advantage. They can anticipate customer needs, develop more personalized marketing plans, and create products and services that meet those needs.

Market Segmentation: Based on information-seeking trends and past knowledge, consumer behavior research helps identify segments within a target market. Through this segmentation, companies can focus their marketing activities on specific groups, thereby increasing their chances of success.

Conclusion

This essay investigates the relationship between consumer knowledge levels and information-searching behaviors: knowledgeable people will find more information about one product and less knowledgeable people about one product will directly buy and are not going to search for more information.

Consumers with prior knowledge (PK) at the time of purchase will be more confident and know what products are really good. However, when faced with a situation contradicting their initial information, consumers with high PK tend to search more until they find the product, they think is reasonable. Consumers without PK will not act in this regard.

PK makes consumers confident about their search behavior; however, the same is not true for people without PK. Consumers' PK about the products may lead them to act differently and hence is different to study from marketers' point of view. Especially as we found that: when consumers' PK about the products is not in line with the reality, they would opt to search for more options and wander more. This could translate into consumers opting for products of other brands and designs. Also, this might lead to consumers forming negative perceptions about the products that were not in line with their PK. Hence, marketers need to update, and educate the consumer's PK for them to have a similar behavior as we saw in the condition: consumers with PK and in-line of the products attribute.

In conclusion, studying past knowledge and information search activity about consumer behavior yields insightful information that can help businesses become more competitive in today's fast-paced market and develop more successful marketing plans and customer experiences.

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Producing Multilinear Regression Models in Predicting Investor Sentiment in Capital Markets By Eron Lin

Literature review

The aim of a linear regression model is ultimately to model the relationship between the dependant variable (y_i) and the independent variables ($x_i, x_{i1}, x_{i2}, \dots, x_{ik}, k \in \mathbb{Z}$). As a result, the model is capable of predicting the dependent variable using one or more independent variables (Greene, 2002). Hence this method is deemed as a valid method to model investor sentiment (Bevans, 2020). The linear regression model, by name, assumes a linear relationship between these variables, which can be typically formulated as:

$$y_i = f(x_{i1}, x_{i2}, \dots, x_{ik}) + \epsilon_i$$

or

$$y_i = \beta_0 + \beta_1 x_{i1} + \dots + \beta_k x_{ik} + \epsilon_i$$

Where:

y_i is the dependent variable from the 'i' th observation, and in this study, it will be the investor sentiment

$x_{i1}, x_{i2}, \dots, x_{ik}$ are the independent variables that influences investor sentiment

$\beta_0, \beta_1, \dots, \beta_k$ are the coefficients/parameters to be calculated

ϵ_i is the uncertainty or 'noise' within the 'i' th observation which accounts for the errors and the unexplained variations of y_i , where $\epsilon_i \sim N(0, \sigma^2)$.

The primary objective in a linear regression model is to estimate the coefficients of the independent variables, also known as the parameters ($\beta_0, \beta_1, \dots, \beta_k$) that best fit the data, typically using the OLS method.

The objective of the OLS method is to find the parameter by estimating the coefficients of $\beta_0, \beta_1, \dots, \beta_k$ to minimize the sum of squares residuals (SSR). In the instance for a linear regression model, there will only be one parameter β , which can be efficiently predicted using the OLS method. A linear regression model:

$$y = X\beta + \epsilon$$

The reason for minimizing the sum squares residual is to create a linear model that best fits the data points. The SSR can be calculated as:

$$SSR = \epsilon'\epsilon = (y - X\beta)'(y - X\beta)$$

This can also be written in a scalar form:

$$\epsilon = \sum_{i=1}^n (y_i - (\beta_0 + \beta x_i))^2$$

To minimize the SSR, treat the equation $(y - X\beta)'(y - X\beta)$ like concave up parabola and find the minimum or turning point of the parabola.

By expanding the RHS of the equation $SSR = (y - X\beta)'(y - X\beta)$:

$$SSR = (y' - X'\beta')(y - X\beta)$$

$$SSR = y'y - (\beta'X'y) - y'X\beta + \beta'X'X\beta$$

As $(c)' = c$, where c is a scalar quantity

$$SSR = y'y - \beta'X'y - y'X\beta + \beta'X'X\beta$$

$$SSR = y'y - 2y'X\beta + \beta'X'X\beta$$

And as the goal is to find the minimum β , take the derivative respect to β on both sides

$$\frac{\partial SSR}{\partial \beta} = -2X'y + 2X'X\beta$$

$0 = -2X'y + 2X'X\beta$ to find the minimum turning point

$$2X'y = 2X'X\beta$$

$$\beta = (X'X)^{-1}X'y$$

This solution is the OLS estimator that is used to solve the parameter estimates that minimizes SSR and ensure an accurate linear regression model (Wolfram MathWorld, 2024). This method of using the OLS assumes that $X'X$ has an inverse. The minimisation of the residual is considered essential for the modeling of investor sentiment, to ensure the model's accuracy.

Statistical Testing

Statistical testing is a method used to make inferences or draw conclusions about a population based on sample data. The primary goal is to determine whether the observed data deviates significantly from a specified hypothesis. Below is a concise explanation of statistical testing with relevant mathematical equations.

Key Concepts:

1. Null Hypothesis (H_0): A statement that there is no effect or no difference. It is the hypothesis that the test aims to reject.
2. Alternative Hypothesis: A statement that indicates the presence of an effect or a difference.
3. Test Statistic: A standardized value calculated from sample data, used to decide whether to reject the null hypothesis.

4. P-value: The probability of observing a test statistic as extreme as, or more extreme than, the observed value under the null hypothesis.
5. Significance Level (α): A threshold probability set before testing. If the p-value is less than α , the null hypothesis is rejected. In my study, due to the small amount of indicators being selected, my significance level α is 0.05. Therefore, if p-value $< \alpha$, reject H_0 . If p-value $\geq \alpha$, fail to reject H_0 .

The p-value is calculated to determine the statistical significance of a predictor in a regression model. It indicates the probability of obtaining test results at least as extreme as the observed results, under the null hypothesis.

First, the t-value is calculated for each coefficient in the regression model using the formula:

$$t = \frac{\widehat{\beta}_k}{SE(\widehat{\beta}_k)}$$

Where:

$\widehat{\beta}_k$ is the estimated coefficient

$SE(\widehat{\beta}_k)$ is the standard error of the estimated coefficient

Both are estimated using the OLS method

Then, the degrees of freedom (df) for t-test in regression is calculated. Df refers to the number of independent pieces of information that go into the estimation of a parameter.

Degrees of freedom are used to assess the goodness of fit of a regression model.

In multiple linear regression, the degrees of freedom for the residuals are calculated as:

$$df = n - k - 1$$

Where:

n is the number of observations

k is the number of predictors (indicators) excluding the intercept (β_0)

Then, using a statistical software, such as minitab, use the t-value and the df to obtain the cumulative probability, then calculate the p-value using:

$$p \text{ value} = 2 \times (1 - CDF(|t|))$$

Where:

$CDF(|t|)$ is the cumulative distribution function of the t-distribution evaluated at the absolute value of the calculated t-value.

These p-values help determine whether the predictors in the model are statistically significant. For each coefficient, the t-value is compared against the critical value from the t-distribution with the appropriate degrees of freedom. The p-value is then derived from this comparison, guiding the decision to accept or reject the null hypothesis for each predictor.

Popular ways of quantifying investor sentiment that are used

Quantifying investor sentiment is essential and stems into multiple fields of finance and economics. It is a crucial indicator that aids in decision making in the field of capital markets in finance and economics (Nguyen et al., 2012).

The most popular method that is used is arguably The University of Michigan Consumer Sentiment Index, or the MCSI. This index derived from a monthly survey which measures consumer sentiment regarding personal financial situations, short-term and long-term economic conditions.

Multiple linear regression can be used to estimate the relationship between two or more independent variables and one dependent variable, making it suitable for analyzing consumer sentiment (Bevans, 2020).

After the qualitative results from the survey is collated, the results are aggregated into a single number or an 'index' that illustrates the investor's sentiments.

Thus, the monthly MCSI will be the dependent variable that will be utilized to model the investor sentiment in the multilinear regression analysis that will be conducted to build the model.

Methodology

1. Conduct a multilinear regression analysis on the variables to model a multilinear model with the dependent variable as investor sentiment using the MCSI and the other dependent indicators.
2. Eliminate unnecessary variables using statistical testing.

Indicators to be analyzed in factor analysis

The indicators are chosen based on their ability to reflect economic sentiments and market dynamics. Each selected indicator provides a perspective on market trends, investor behavior and overall the economic health. By analyzing these indicators, insights into potential market movements and shifts in investor sentiment can be discerned, which are critical for making investment decisions.

All of these indicators will be collated and analyzed on a monthly average basis to accommodate the MCSI that is collated on a monthly average. The data of the indicators and the MCSI will be collated from 1st February 2021 to 1st February 2024.

1. The volatility index (VIX)

Often referred to as the “fear index”, the index measures the implied volatility of options on the Standard and Poor’s 100 stock index. It is often referred to as the “investor fear gauge” (Baker, 2007).

2. Chicago Board Options Exchange (CBOE) Put-Call Ratio

The ratio measures the number of put options traded relative to call options. A higher ratio can indicate bearish sentiment, as more traders are betting against the market, while a lower ratio suggests bullish sentiment (Pan, 2004). This calculated using the formula:

$$Put/call\ ratio = \frac{total\ puts}{total\ calls}$$

3. Standard and Poor 500 index (SPX)

The S&P 500 is a strong indicator of consumer sentiment because it includes 500 of the largest U.S. companies, representing diverse industries. Stock performance in the index reflects corporate health and consumer spending, influencing overall economic perceptions. Movements in the S&P 500 often correlate with changes in consumer confidence, serving as both a reflective and predictive economic tool.

4. ICE U.S dollar index (DXY)

The DXY is calculated using a geometrically weighted average of the dollar’s value compared to a basket of six major world currencies. Movements in the DXY can reflect macroenvironments, as a rising index might indicate confidence in the U.S economy relative to other economies, potentially representing an increase in investor sentiment (Bruno & Shin, 2015). It is calculated using the formula:

$$DXY = 50.14348112 \times EURUSD^{-0.576} \times USDJPY^{0.136} \times GBPUSD^{-0.119} \times USDCAD^{0.091} \times USDSEK^{0.042}$$

5. Nike Inc. (NKE)

Nike Inc. (NKE) is a valuable indicator for evaluating consumer sentiment, particularly within the consumer discretionary sector. The company's performance is closely linked to consumer sentiment and spending habits because it sells non-essential, higher-margin goods. When consumers feel financially secure and optimistic about the economy, they are more likely to spend on premium brands like Nike. Additionally, Nike's quick responsiveness to market trends and consumer preferences, such as its investment in sustainability and digital sales platforms, reflects its alignment with consumer values and expectations, which can serve as a leading indicator of shifts in consumer behavior and sentiment (Goldman, 2020).

6. NYSE composite index (NYA)

The NYSE composite index is a stock market index that covers all common stocks listed on the New York Stock exchange, which includes ADRs, REITs, tracking stocks and foreign listings.

This index provides a comprehensive view of the market's performance across different sectors, as it factors in companies from each of the ten industries listed in the Industry Classification Benchmark (NYSE, 2018).

First round analysis

Date	Put/Call	Close of DXY	Close of nya	Close of vix	Close of S&P	Close of NKE	MCSI
1/5/23	0.98	102.145268	15535.8855	16.08	4167.9	127.919998	59.0
2/5/23	1.02	101.870889	15314.5671	17.780001	4119.6	127.260002	59.0
3/5/23	1.11	101.215215	15233.8515	18.34	4090.8	126.739998	59.0
4/5/23	0.91	101.373931	15117.6718	20.09	4061.2	123.669998	59.0
5/5/23	0.95	101.282417	15380.8718	17.190001	4136.2	126.589996	59.0
8/5/23	1.04	101.403461	15391.2711	16.98	4138.1	126.879997	59.0
9/5/23	0.93	101.617215	15352.8127	17.709999	4119.2	125.099998	59.0
10/5/23	0.96	101.394906	15349.1678	16.940001	4137.6	123.510002	59.0
11/5/23	0.9	102.063546	15263.07	16.93	4130.6	122.220001	59.0
12/5/23	0.92	102.704898	15246.3634	17.030001	4124.1	120.209999	59.0
15/5/23	0.94	102.420766	15322.5565	17.120001	4136.3	119.830002	59.0
16/5/23	0.94	102.623075	15129.2526	17.99	4109.9	116.480003	59.0
17/5/23	0.99	102.879547	15313.9186	16.870001	4158.8	116.980003	59.0
18/5/23	0.82	103.488396	15345.431	16.049999	4198.1	118.870003	59.0
19/5/23	0.9	103.192803	15324.3227	16.809999	4192	114.760002	59.0
22/5/23	0.82	103.260012	15318.849	17.209999	4192.6	110.18	59.0
23/5/23	1	103.506939	15172.2687	18.530001	4145.6	108.779999	59.0
24/5/23	1.06	103.850746	15022.8886	20.030001	4115.2	108.290001	59.0
25/5/23	0.9	104.191501	14975.9703	19.139999	4151.3	107.480003	59.0
26/5/23	0.88	104.226103	15078.69	17.950001	4205.4	107.510002	59.0
30/5/23	0.9	104.057468	14994.6443	17.459999	4205.5	106.519997	59.0
31/5/23	1.06	104.146321	14887.1415	17.940001	4179.8	105.260002	59.0

1/6/23	0.88	103.545069	15031.0854	15.65	4221	103.629997	64.2
2/6/23	0.76	104.041165	15345.1948	14.6	4282.4	107.779999	64.2
5/6/23	0.97	104.013933	15275.2124	14.73	4273.8	105.199997	64.2
6/6/23	0.93	104.135459	15391.8039	13.96	4283.9	106.190002	64.2
7/6/23	0.9	104.110206	15469.6333	13.94	4267.5	107.089996	64.2
8/6/23	0.87	103.300328	15502.6447	13.65	4293.9	106.199997	64.2
9/6/23	0.84	103.552603	15499.9108	13.83	4298.9	105.860001	64.2
12/6/23	0.88	103.581717	15548.4739	15.01	4338.9	106.830002	64.2
13/6/23	0.82	103.30276	15667.7923	14.61	4369	106.779999	64.2
14/6/23	1.01	103.009397	15642.729	13.88	4372.6	112.860001	64.2
15/6/23	0.88	102.105694	15826.3541	14.5	4425.8	112.410004	64.2
16/6/23	0.82	102.299355	15795.1182	13.54	4409.6	113.589996	64.2
20/6/23	0.84	102.496004	15648.9211	13.88	4388.7	109.540001	64.2
21/6/23	0.91	102.029623	15657.0038	13.2	4365.7	109.980003	64.2
22/6/23	0.83	102.403446	15600.7012	12.91	4381.9	110.459999	64.2
23/6/23	0.89	102.867234	15469.3472	13.44	4348.3	109.519997	64.2
26/6/23	0.9	102.740679	15518.7367	14.25	4328.8	111.739998	64.2
27/6/23	0.92	102.515724	15646.6794	13.74	4378.4	113.610001	64.2
28/6/23	0.84	102.95672	15617.3603	13.43	4376.9	113.029999	64.2
29/6/23	0.87	103.344945	15737.3775	13.54	4396.4	113.370003	64.2
30/6/23	0.88	102.921146	15875.9135	13.59	4450.4	110.370003	64.2
3/7/23	0.84	102.961914	15918.5006	13.57	4455.6	109.110001	71.5
5/7/23	0.95	103.342067	15835.5309	14.18	4446.8	107.099998	71.5
6/7/23	0.93	103.06911	15641.6652	15.44	4411.6	105.099998	71.5
7/7/23	0.83	102.266441	15671.6262	14.83	4398.9	104.459999	71.5
10/7/23	0.86	101.940557	15748.8652	15.07	4409.5	105.779999	71.5
11/7/23	0.74	101.617228	15897.3125	14.84	4439.3	107.389999	71.5
12/7/23	0.86	100.541536	16011.277	13.54	4472.2	107.760002	71.5

13/7/23	0.83	99.75373	16106.8462	13.61	4510	107.839996	71.5
14/7/23	0.84	99.959929	16040.2287	13.34	4505.4	107.949997	71.5
17/7/23	0.84	99.882087	16054.1682	13.48	4522.8	108.709999	71.5
18/7/23	0.78	99.942193	16156.5108	13.3	4555	109.720001	71.5
20/7/23	0.87	100.780999	16263.7105	13.99	4534.9	107.529999	71.5
24/7/23	0.82	101.426393	16369.138	13.91	4554.6	108.769997	71.5
25/7/23	0.87	101.304165	16385.175	13.86	4567.5	108.300003	71.5
26/7/23	0.96	101.063647	16418.21	13.19	4566.8	109.300003	71.5
27/7/23	0.96	101.73907	16270.5965	14.41	4537.4	107.669998	71.5
28/7/23	0.92	101.700709	16363.2605	13.33	4582.2	108.620003	71.5
31/7/23	0.9	101.873418	16427.2891	13.63	4589	110.389999	71.5
1/8/23	0.84	102.008918	16356.5139	13.93	4576.7	109.400002	69.4
2/8/23	0.97	102.566425	16174.5363	16.09	4513.4	107.510002	69.4
3/8/23	0.88	102.458605	16125.4227	15.92	4501.9	108.639999	69.4
4/8/23	1.01	102.00859	16071.0593	17.1	4478	108.809998	69.4
7/8/23	1.03	102.067417	16208.2275	15.77	4518.4	110.480003	69.4
8/8/23	1	102.54886	16176.3503	15.99	4499.4	109.690002	69.4
9/8/23	0.98	102.480841	16135.7725	15.96	4467.7	109.690002	69.4
10/8/23	1.07	102.61655	16135.2189	15.85	4468.8	109.029999	69.4
11/8/23	1	102.852809	16143.3776	14.84	4464.1	108.089996	69.4
14/8/23	0.97	103.163777	16116.0504	14.82	4489.7	107.639999	69.4
15/8/23	1.05	103.219268	15911.31	16.459999	4437.9	106.550003	69.4
16/8/23	1.26	103.449307	15818.1094	16.780001	4404.3	106.529999	69.4
17/8/23	1.09	103.401435	15734.3844	17.889999	4370.4	105.050003	69.4
21/8/23	0.91	103.325993	15746.2111	17.129999	4399.8	102.860001	69.4
22/8/23	0.95	103.588356	15690.2832	16.969999	4387.6	101.459999	69.4
23/8/23	1.18	103.367765	15823.2727	15.98	4436	98.75	69.4
24/8/23	1.12	104.098666	15683.006	17.200001	4376.3	97.629997	69.4

30/8/23	1.09	103.101992	16074.2242	13.88	4514.9	102.099998	69.4
31/8/23	0.95	103.626534	16000.3726	13.57	4507.7	101.709999	69.4
1/9/23	1.04	104.264252	16091.7927	13.09	4515.8	102.360001	67.8
5/9/23	1.05	104.754533	15942.4802	14.01	4496.8	100.32	67.8
6/9/23	1.23	104.862415	15891.5301	14.45	4465.5	100.18	67.8
7/9/23	1.12	105.063003	15864.1914	14.4	4451.1	97.93	67.8
8/9/23	1.05	105.05584	15878.9879	13.84	4457.5	97.669998	67.8
11/9/23	1.01	104.54024	15949.4422	13.8	4487.5	96.790001	67.8
12/9/23	0.99	104.570101	15953.9127	14.23	4461.9	96.300003	67.8
13/9/23	1.27	104.741889	15926.6388	13.48	4467.4	96.129997	67.8
14/9/23	1.07	105.372714	16089.4801	12.82	4505.1	97.190002	67.8
15/9/23	0.94	105.331227	15973.6787	13.79	4450.3	96.260002	67.8
18/9/23	1.03	105.081079	15952.5238	14	4453.5	95.510002	67.8
19/9/23	0.91	105.109071	15929.0083	14.11	4443.9	94.620003	67.8
20/9/23	1.08	105.432589	15859.6187	15.14	4402.2	94.040001	67.8
21/9/23	1.15	105.383865	15601.6009	17.540001	4330	91.589996	67.8
22/9/23	1.16	105.582297	15569.5128	17.200001	4320.1	90.849998	67.8
25/9/23	1.09	105.93148	15593.7299	16.9	4337.4	90.599998	67.8
26/9/23	1.14	106.177031	15381.5807	18.940001	4273.5	90.169998	67.8
27/9/23	1.29	106.675855	15394.688	18.219999	4274.5	89.419998	67.8
28/9/23	1	106.148598	15478.0734	17.34	4299.7	89.629997	67.8
29/9/23	1.04	106.17392	15398.2142	17.52	4288.1	95.620003	67.8
2/10/23	1.09	107.039644	15230.013	17.610001	4288.4	94.559998	63.8
3/10/23	1.13	107.09604	15043.4195	19.780001	4229.4	95.089996	63.8
4/10/23	1.59	106.777099	15070.9137	18.58	4263.8	95.889999	63.8
5/10/23	1.3	106.356748	15072.9888	18.49	4258.2	95.790001	63.8
6/10/23	0.96	106.100579	15214.0226	17.450001	4308.5	97.110001	63.8
9/10/23	1.08	106.033448	15318.0772	17.700001	4335.7	96.879997	63.8

10/10/23	0.97	105.73211	15450.2352	17.030001	4358.2	97.620003	63.8
11/10/23	1.26	105.668185	15487.7758	16.09	4376.9	98.650002	63.8
12/10/23	1.11	106.540533	15329.5491	16.690001	4349.6	99.25	63.8
13/10/23	1.06	106.672218	15323.6966	19.32	4327.8	99.910004	63.8
16/10/23	1.05	106.239644	15484.5003	17.209999	4373.6	102.040001	63.8
17/10/23	1.05	106.207235	15541.3772	17.879999	4373.2	103.010002	63.8
18/10/23	1.02	106.539418	15324.9628	19.219999	4314.6	103.769997	63.8
19/10/23	1.05	106.25547	15196.3735	21.4	4278	103.050003	63.8
20/10/23	1.04	106.16257	15033.3077	21.709999	4224.2	102.669998	63.8
23/10/23	0.89	105.596303	14946.0106	20.370001	4217	102.809998	63.8
24/10/23	0.91	106.248959	15025.7565	18.969999	4247.7	105.18	63.8
25/10/23	1.26	106.577547	14914.1163	20.190001	4186.8	103.540001	63.8
26/10/23	1.12	106.58243	14858.6974	20.68	4137.2	100.019997	63.8
27/10/23	1.17	106.581077	14675.7793	21.27	4117.4	97.980003	63.8
30/10/23	1.09	106.1635	14825.8923	19.75	4166.8	101.800003	63.8
31/10/23	1.09	106.670774	14919.2008	18.139999	4193.8	102.769997	63.8
1/11/23	0.99	106.509409	15002.5529	16.870001	4237.9	100.879997	61.3
2/11/23	1	106.184893	15332.6035	15.66	4317.8	105.080002	61.3
3/11/23	0.91	105.069484	15475.1981	14.91	4358.3	107.059998	61.3
6/11/23	1.09	105.276467	15440.4973	14.89	4366	107.25	61.3
7/11/23	0.98	105.538813	15388.484	14.81	4378.4	109.360001	61.3
8/11/23	1.18	105.533969	15352.1933	14.45	4382.8	109.389999	61.3
9/11/23	1.13	105.936526	15235.1841	15.29	4347.4	107	61.3
10/11/23	1.12	105.800629	15388.4364	14.17	4415.2	106.110001	61.3
13/11/23	1.13	105.641523	15403.1421	14.76	4411.6	104.199997	61.3
14/11/23	0.98	104.160301	15732.667	14.16	4495.7	105.75	61.3
15/11/23	0.81	104.339036	15765.0187	14.18	4502.9	107.82	61.3
16/11/23	0.91	104.362999	15716.546	14.32	4508.2	107.610001	61.3

17/11/23	0.86	103.815	15813.4605	13.8	4514	105.959999	61.3
20/11/23	0.95	103.465879	15881.6271	13.41	4547.4	106.32	61.3
21/11/23	0	103.539198	15861.5681	13.35	4538.2	106.550003	61.3
22/11/23	0.94	103.863033	15907.8935	12.85	4556.6	107.919998	61.3
24/11/23	1.11	103.414616	15983.8173	12.46	4559.3	107.639999	61.3
27/11/23	1.12	103.149419	15930.8895	12.69	4550.4	107.959999	61.3
28/11/23	0.98	102.65448	15929.146	12.69	4554.9	108.75	61.3
29/11/23	0.81	102.826935	15962.994	12.98	4550.6	110.370003	61.3
30/11/23	0.89	103.386423	16088.8393	12.92	4567.8	110.269997	61.3
1/12/23	0.84	103.193325	16263.752	12.63	4594.6	113.480003	69.7
4/12/23	0.82	103.606029	16232.8231	13.08	4569.8	115.150002	69.7
5/12/23	0.91	103.957613	16123.0357	12.85	4567.2	115.410004	69.7
6/12/23	0.89	104.145631	16092.3746	12.97	4549.3	116.110001	69.7
7/12/23	0.93	103.637281	16136.8479	13.06	4585.6	114.809998	69.7
8/12/23	0.89	103.982561	16207.7571	12.35	4604.4	115.910004	69.7
11/12/23	0.92	104.067605	16274.4351	12.63	4622.4	118.610001	69.7
12/12/23	0.99	103.795713	16285.9372	12.07	4643.7	119.639999	69.7
13/12/23	1.01	102.893581	16560.7077	12.19	4707.1	121.169998	69.7
14/12/23	0.81	102.029825	16723.9156	12.48	4719.6	121.019997	69.7
15/12/23	0.77	102.593506	16609.8402	12.28	4719.2	121.550003	69.7
18/12/23	0.96	102.470113	16656.7574	12.56	4740.6	121.139999	69.7
19/12/23	0.88	102.191679	16798.4003	12.53	4768.4	122.639999	69.7
20/12/23	0.93	102.393851	16534.7174	13.67	4698.4	121.43	69.7
21/12/23	0.94	101.774038	16609.8402	13.65	4746.8	122.529999	69.7
22/12/23	0.87	101.708501	16770.4496	13.03	4754.6	108.040001	69.7
26/12/23	0.92	101.518441	16859.4915	12.99	4774.8	108.019997	69.7
27/12/23	1.08	100.867327	16898.3354	12.43	4781.6	107.129997	69.7
28/12/23	0.89	101.195633	16890.5812	12.47	4783.4	108.82	69.7

29/12/23	0.93	101.378539	16852.8909	12.45	4769.8	108.57	69.7
2/1/24	0.94	102.205925	16841.6194	13.2	4742.8	106.550003	79.0
3/1/24	1.05	102.409559	16718.6538	14.04	4704.8	104.040001	79.0
4/1/24	0.95	102.411311	16715.7061	14.13	4688.7	102.300003	79.0
5/1/24	1.18	102.435448	16758.2362	13.35	4697.2	102.080002	79.0
8/1/24	0.84	102.22304	16885.3686	13.08	4763.5	103.620003	79.0
9/1/24	0.93	102.482147	16773.0717	12.76	4756.5	102.739998	79.0
10/1/24	1.28	102.330923	16818.879	12.69	4783.4	103.769997	79.0
11/1/24	1.04	102.24275	16781.1192	12.44	4780.2	105.900002	79.0
12/1/24	0.88	102.438543	16799.5374	12.7	4783.8	105.059998	79.0
16/1/24	1.01	103.362564	16639.3819	13.84	4766	101.720001	79.0
17/1/24	1.01	103.369104	16522.8286	14.79	4739.2	100.82	79.0
18/1/24	0.91	103.372003	16616.2896	14.13	4780.9	100.940002	79.0
19/1/24	0.88	103.239314	16729.5533	13.3	4839.8	101.779999	79.0
22/1/24	0.82	103.381178	16779.4923	13.19	4850.4	100.559998	79.0
23/1/24	0.91	103.492009	16800.8631	12.55	4864.6	101.900002	79.0
24/1/24	0.97	103.347904	16769.249	13.14	4868.6	100.760002	79.0
25/1/24	0.94	103.534337	16889.5228	13.45	4894.2	100.769997	79.0
26/1/24	0.91	103.47381	16949.1054	13.26	4891	102.75	79.0
29/1/24	0.94	103.436896	17040.5958	13.6	4927.9	103.879997	79.0
30/1/24	0.91	103.372742	17089.4646	13.31	4925	104.18	79.0
31/1/24	0.92	103.625744	16911.1313	14.35	4845.6	101.529999	79.0
1/2/24	1	103.017498	17115.5787	13.88	4906.2	101.760002	76.9
2/2/24	1.04	103.961641	17101.9706	13.85	4958.6	100.709999	76.9
5/2/24	0.93	104.446282	17004.7756	13.67	4942.8	99.68	76.9
6/2/24	0.82	104.149862	17135.4785	13.06	4954.2	102.610001	76.9
7/2/24	0.98	104.027136	17212.3225	12.83	4995.1	103.790001	76.9
8/2/24	0.84	104.143797	17252.3218	12.79	4997.9	103.769997	76.9

9/2/24	0.82	104.080351	17275.8672	12.93	5026.6	104.5	76.9
12/2/24	1	104.162501	17332.4589	13.93	5021.8	107.18	76.9
13/2/24	0.89	104.880967	17068.5377	15.85	4953.2	105	76.9
14/2/24	0.96	104.677598	17240.1867	14.38	5000.6	106.330002	76.9
15/2/24	0.85	104.297535	17434.9285	14.01	5029.7	106.050003	76.9
16/2/24	0.93	104.275213	17409.2963	14.24	5005.6	103.510002	76.9
20/2/24	0.93	104.058787	17340.166	15.42	4975.5	103.300003	76.9
21/2/24	1.09	103.959419	17382.6801	15.34	4981.8	105.269997	76.9
22/2/24	0.94	103.896554	17565.0677	14.54	5087	105.080002	76.9
23/2/24	0.96	103.961379	17616.0231	13.75	5088.8	105.629997	76.9
26/2/24	1	103.779209	17566.6076	13.74	5069.5	104.540001	76.9
27/2/24	0.97	103.842949	17598.3155	13.43	5078.2	105.150002	76.9
28/2/24	0.87	103.919829	17573.6915	13.84	5069.8	104.349998	76.9
29/2/24	0.93	104.119699	17607.433	13.4	5096.3	103.93	76.9
1/3/24	0.97	103.88483	17728.2678	13.11	5137.1	101.879997	79.4
4/3/24	0.86	103.828089	17748.6958	13.49	5130.9	99.540001	79.4
5/3/24	1.04	103.81495	17669.4866	14.46	5078.6	98.309998	79.4
6/3/24	1.06	103.274912	17801.0419	14.5	5104.8	97.629997	79.4
7/3/24	0.95	102.731657	17927.6197	14.44	5157.4	98.190002	79.4
8/3/24	0.92	102.740529	17889.6205	14.74	5123.7	99.160004	79.4
11/3/24	1.03	102.828661	17863.6888	15.22	5117.9	101.080002	79.4
12/3/24	1.07	102.910441	17974.0616	13.84	5175.3	100.18	79.4
13/3/24	0.87	102.785202	18018.6327	13.75	5165.3	101.360001	79.4
14/3/24	0.9	103.378127	17886.2669	14.4	5150.5	100.260002	79.4
15/3/24	0.8	103.446227	17848.0847	14.41	5117.1	99.639999	79.4
18/3/24	0.86	103.586765	17882.315	14.33	5149.4	98.739998	79.4
19/3/24	1.02	103.841235	17975.7883	13.82	5178.5	99.959999	79.4
20/3/24	0.98	103.291348	18130.0787	13.04	5224.6	100.269997	79.4

21/3/24	0.99	104.003999	18214.1209	12.92	5241.5	100.82	79.4
22/3/24	1.29	104.429968	18112.0359	13.06	5234.2	93.860001	79.4
25/3/24	1.02	104.225272	18077.1508	13.19	5218.2	93.75	79.4
26/3/24	1	104.293601	18059.188	13.24	5203.6	92.580002	79.4
27/3/24	1.02	104.435096	18255.2361	12.78	5248.5	94.129997	79.4
28/3/24	1.19	104.539114	18312.6695	13.01	5254.4	93.980003	79.4
1/4/24	0.94	105.010118	18216.1943	13.65	5243.8	92.559998	77.2
2/4/24	0.95	104.779055	18107.5282	14.61	5205.8	90.949997	77.2
3/4/24	1.06	104.223761	18146.6372	14.33	5211.5	90.330002	77.2
4/4/24	1.03	104.207226	17982.4875	16.35	5147.2	89.07	77.2
5/4/24	1.19	104.287159	18122.2612	16.030001	5204.3	88.839996	77.2
8/4/24	1.02	104.120421	18154.3696	15.19	5202.4	90	77.2
9/4/24	1.05	104.097374	18171.1951	14.98	5209.9	91	77.2
10/4/24	1.01	105.176958	17947.2982	15.8	5160.6	89	77.2
11/4/24	0.98	105.26538	17915.1952	14.91	5199.1	92	77.2
12/4/24	0.85	106.013485	17639.0384	17.309999	5123.4	92	77.2
15/4/24	0.92	106.175831	17506.9279	19.23	5061.82	93.099998	77.2
16/4/24	0.83	106.332304	17413.9807	18.4	5051.41	93.389999	77.2
17/4/24	1.27	105.929738	17403.4376	18.209999	5022.21	94.839996	77.2
18/4/24	0.99	106.192859	17388.0883	18	5011.12	95.739998	77.2
19/4/24	1.03	106.118034	17458.7682	18.709999	4967.23	94.529999	77.2
22/4/24	0.91	106.134679	17602.1861	16.940001	5010.6	94.190002	77.2
23/4/24	1.03	105.677363	17792.7575	15.69	5070.55	94.019997	77.2
24/4/24	0.94	105.822316	17758.0811	15.97	5071.63	94.639999	77.2
25/4/24	0.93	105.576473	17731.5571	15.37	5048.42	93.940002	77.2
26/4/24	1	106.093225	17763.2672	15.03	5099.96	94.120003	77.2
29/4/24	0.93	105.672457	17831.0693	14.67	5116.17	94.059998	77.2
30/4/24	0.94	106.321441	17603.3368	15.65	5035.69	92.260002	77.2

Model

$$\text{MCSI} = 140.0 + 2.02 \text{ Put/Call} - 1.199 \text{ Close of DXY} - 0.00029 \text{ Close of nya} + 0.164 \text{ Close of vix} + 0.01705 \text{ Close of S\&P} - 0.2288 \text{ Close of NKE}$$

S	R-sq	R-sq(adj)	R-sq(pred)
2.81859	83.49%	83.08%	82.51%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	140.0	25.0	5.60	0.000	
Put/Call	2.02	1.53	1.32	0.188	1.29
Close of DXY	-1.199	0.202	-5.92	0.000	3.13
Close of nya	-0.00029	0.00139	-0.21	0.833	55.26
Close of vix	0.164	0.124	1.32	0.189	2.15
Close of S&P	0.01705	0.00412	4.14	0.000	59.39
Close of NKE	-0.2288	0.0334	-6.84	0.000	2.39

ANOVA

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	6	9603.9	1600.65	201.48	0.000
Put/Call	1	13.9	13.85	1.74	0.188
Close of DXY	1	278.6	278.59	35.07	0.000
Close of nya	1	0.4	0.35	0.04	0.833
Close of vix	1	13.8	13.79	1.74	0.189
Close of S&P	1	136.0	136.05	17.12	0.000
Close of NKE	1	371.8	371.78	46.80	0.000
Error	239	1898.7	7.94		
Total	245	11502.6			

Analysis

The adjusted R-squared value indicates that the model explains approximately 83% of the variability in the MSCI, which is relatively high, measuring a high level of correlation.

Close of DXY, Close of S&P, and Close of NKE have statistically significant p-values (< 0.001), indicating a strong relationship with the MCSI.

Improvements

Removing Close of NYA or Close of S&P due to high VIF values. Alternatively, combine highly correlated variables through techniques like Principal Component Analysis (PCA) to reduce multicollinearity.

Variable Selection: Use stepwise regression or other variable selection methods to refine the model and retain only significant predictors.

Backward selection

In this process, the aim is to remove insignificant indicators for a more accurate model. Backward selection removes the least significant variables until only significant variables remain, preventing overfitting and improving the interpretability of the model. The backward selection process will be conducted through observing the p-values of each indicator. As the initial model has 6 indicators, $p < 0.05$ will be taken as a benchmark.

Put/Call Ratio, Close of NYA, and Close of VIX are not statistically significant ($p > 0.05$). Variance Inflation Factor (VIF): High VIF for Close of NYA (55.26) and Close of S&P (59.39) indicates multicollinearity, which can inflate the standard errors of the coefficients.

Hence, the first step of the backward selection process is to remove the nya indicator:

Second round analysis

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	136.9	20.2	6.77	0.000	
Close of NKE	-0.2286	0.0334	-6.85	0.000	2.39
Close of S&P	0.016192	0.000743	21.81	0.000	1.94
Close of vix	0.154	0.115	1.34	0.183	1.86
Close of DXY	-1.176	0.169	-6.95	0.000	2.19
Put/Call	1.98	1.51	1.31	0.193	1.26

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
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2.8129	83.49	83.15%	82.66%
7	%		

Interpretation of Results

Significant Predictors:

Close of NKE: Coefficient = -0.2286, ($p < 0.001$) Indicates a significant negative relationship with MCSI.

Close of S&P: Coefficient = 0.0162, ($p < 0.001$) Indicates a significant positive relationship with MCSI.

Close of DXY: Coefficient = -1.176, ($p < 0.001$) Indicates a significant negative relationship with MCSI.

Non-Significant Predictors:

Close of VIX: Coefficient = 0.154, $p = 0.183$

Put/Call: Coefficient = 1.98, $p = 0.193$

Variance Inflation Factor (VIF):

Close of NKE: VIF = 2.39

Close of S&P: VIF = 1.94

Close of VIX: VIF = 1.86

Close of DXY: VIF = 2.19

Put/Call: VIF = 1.26

All VIF values are below 10, suggesting that multicollinearity is not a serious issue among the remaining predictors.

Next Steps in Backward Selection: Close of VIX and Put/Call have high p -values and could be considered for removal.

Remove the Next Least Significant Predictor: Close of VIX has the highest p -value ($p = 0.183$)

Therefore, remove Close of VIX from the model.

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	133.5	20.1	6.65	0.000	
Close of NKE	-0.2325	0.0333	-6.99	0.000	2.37
Close of S&P	0.015703	0.000647	24.27	0.000	1.47
Close of DXY	-1.097	0.159	-6.91	0.000	1.93
Put/Call	2.24	1.50	1.49	0.137	1.24

Next Steps in Backward Selection: Put/Call have high p -values and could be considered for removal.

Remove the Next Least Significant Predictor: Put/Call has the highest p -value ($p = 0.137$) Therefore, remove Put/Call from the model.

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	132.6	20.1	6.59	0.000	
Close of NKE	-0.2418	0.0328	-7.37	0.000	2.29
Close of S&P	0.015535	0.000639	24.32	0.000	1.42
Close of DXY	-1.051	0.156	-6.73	0.000	1.85

Final Regression Equation

$$\text{MCSI} = 132.6 - 0.2418 \text{ Close of NKE} + 0.015535 \text{ Close of S\&P} - 1.051 \text{ Close of DXY}$$

Conclusion

The study is aimed to produce multilinear regression models in predicting consumer sentiment in capital markets using various economic indicators. The findings indicate that the model, particularly with the refined selection of variables, can explain a significant portion of the variability in consumer sentiment. Key predictors such as the S&P 500, the DXY index, and Nike's stock performance demonstrated strong relationships with the University of Michigan Consumer Sentiment Index (MCSI), while others like the VIX and Put/Call ratios were found to be less significant. These results highlight the importance of careful variable selection and multicollinearity management in developing robust predictive models. The successful application of multilinear regression underscores its utility in financial analytics, providing valuable insights for investors in anticipating market trends and consumer behavior. Future research could explore incorporating additional or alternative indicators and advanced modeling techniques to further enhance prediction accuracy and applicability.

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Impact of Climate Change on Plant Photosynthesis By Andy Du

Abstract

In recent years, climate change and the rise of atmospheric carbon dioxide has led to numerous changes within the environment. The areas most affected by global warming are the ecosystems that help power and support all the biodiversity on planet Earth. As organisms within their habitats experience detrimental effects in response to increased temperatures and carbon dioxide levels, many are forced to shift their required living conditions and adapt to their new environments. With autotrophic organisms being capable of absorbing carbon dioxide from the atmosphere and producing it in the form of organic molecules through photosynthesis, it is critical to research the impact of climate change on autotrophs that are essential to the environment. The Hubbard Brook Data Set experiment performed by Pamela Templer and her colleagues clearly suggests a correlation between photosynthetic rates and carbon dioxide levels. Though evidence points towards the hypothesis that an increase of carbon dioxide levels in the environment leads to greater photosynthetic rates for plants, it is clear that there are many conditions and variables that ultimately determine plant growth.

Introduction

As of 2024, there have been twelve straight years of a carbon dioxide increase of over 2 ppm (parts per million) on planet Earth, showing the impact that the human footprint has had on the environment (Lindsey, 2024). Autotrophic organisms are capable of absorbing carbon dioxide from the atmosphere and producing their own food in the form of organic molecules through photosynthesis.

Photosynthesis itself begins with the absorption of a photon that excites a specialized chlorophyll molecule (P680), and subsequently ejects an electron from the P680 (Dusenge et al, 2018). This electron travels down the photosynthetic electron transport chain to the ultimate electron acceptor through a series of redox reactions (Dusenge et al, 2018). As the electron progresses down the electron transport chain, a proton concentration gradient forms across the thylakoid membrane that helps generate ATP through the ATP synthase and diffusion of protons down their concentration gradient (Dusenge et al, 2018). The ATP created in this initial step of photosynthesis is then used in the chloroplast of the Calvin-Benson cycle (Dusenge et al, 2018). The enzyme rubisco fixes the absorbed carbon dioxide molecule with RuBP to produce 3-PGA, which with the help of ATP, is reduced into G3P (Dusenge et al, 2018). Some of the G3P is sent back into the Calvin cycle to regenerate RuBP, while the rest is used to help make glucose, sucrose, and other carbon-based molecules (Dusenge et al, 2018). These molecules generated in photosynthesis are later broken down in cellular respiration to help produce ATP and fuel plant metabolism. In this respiration process, the reactants of glucose and oxygen react to generate ATP, while water and carbon dioxide are released as the products (Dusenge et al, 2018). Collectively, the organisms that perform photosynthesis use sunlight and the absorption of carbon dioxide to help create organic compounds such as glucose and release oxygen. With autotrophs serving as producers in the ecosystem, the glucose and other organic molecules they

produce through photosynthesis are crucial for the food chain, and provide a fundamental basis for successful ecosystems.

With autotrophic photosynthesis being so important in the food chain, it is imperative to research the effects to which climate change and increasing carbon dioxide concentrations play upon many of these organisms. Higher carbon dioxide concentrations can cause higher rates of photosynthesis in many plants, which can lead to greater plant growth, above-ground biomass, and yield (van der Kooi et al., [2016](#)). However, higher amounts of atmospheric carbon dioxide can also reduce plant productivity under certain conditions, which makes it critical to understand plant responses to higher levels of carbon dioxide (Thompson et al, 2017). Climatic changes are estimated to have a huge influence on Earth's vegetation and biodiversity, as temperature plays an incredibly significant role on species distribution and its impact across the world (Woodward, 1987). Most biological processes are temperature-sensitive, which means that higher temperatures can significantly alter the thermal environment of plants (Dusenge et al, 2018). Rising amounts of carbon dioxide can both indirectly and directly influence vegetation and wildlife. Increasing amounts of this gas can indirectly influence plant performance through its effect on air temperature and water stress, while carbon dioxide can also directly affect the cell cycle of plants through its role in photosynthesis, which is the entry point for carbon into the biosphere (Dusenge et al, 2018). Additionally, higher carbon dioxide concentrations increase the net rate of photosynthesis for many plants through a greater carbon dioxide substrate availability for Rubisco (Dusenge et al, 2018).

Here, this paper reviews the Hubbard Brook Data Set experiment performed by Pamela Templer and her colleagues, and summarizes the effects of temperature and carbon dioxide levels on photosynthetic rates.

Methods

The "Climate Change Across Seasons Experiment (CCASE) at the Hubbard Brook Experimental Forest: Leaf Level Photosynthesis" experiment researched the effects of climate change on photosynthetic plant rates. The data was downloaded onto the JMP application to help create graphs and visualize the data that showed the change of photosynthetic rates over time from 2015-2017. The experiment used various experimental conditions to help simulate the drastic changes that an increased amount of carbon dioxide could potentially have on the environment.

Results

After collecting results between the years 2015 and 2017, Templer and her group found that on average, the photosynthesis of plants, measured in micromoles of carbon dioxide per meter squared per second, increased linearly as a function of time between the years 2015 and 2017 (*Climate Change*, 2020) (Figure 1). As stated earlier, as of 2024, there have been twelve straight years of a carbon dioxide increase of over 2 ppm (parts per million) on planet Earth. With Templer's experiment set between the years of 2015 and 2017, the rise in atmospheric

carbon dioxide in between this time frame supports the hypothesis that plants increase their photosynthetic rates with higher amounts of carbon dioxide present in the environment (Annual 2017, n.d.). Therefore, Templer’s data clearly supports the hypothesis that an increase in atmospheric carbon dioxide in the environment leads to a proportional increase in photosynthetic rates in plants (*Climate Change*, 2020).

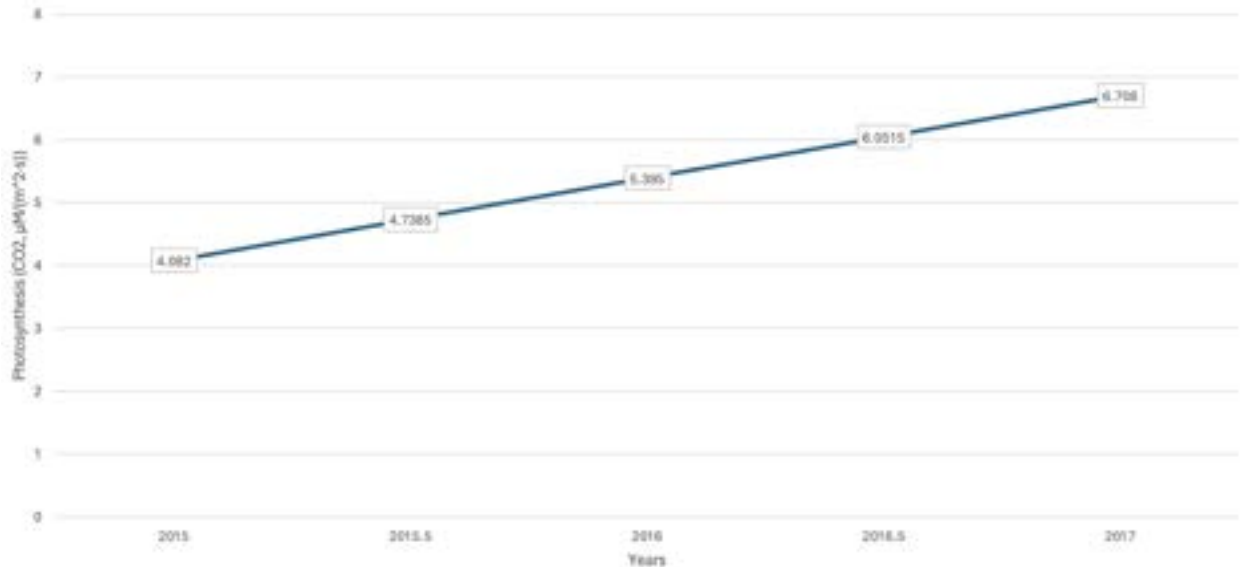


Figure 1: Graph representing the linear relationship between photosynthesis (CO₂, μmol/(m²·s)) and time in the experiment.

In 2017, the average global temperature on Earth was 1.51°F above the 20th century average of 57.0°F (Annual 2017, n.d.). In 2015 and 2016, temperatures increased 1.62°F and 1.69°F respectively, showing the continual increase of global warmth. To study the effect of temperature on photosynthesis, Templer set up six land plots with equal amounts of vegetation and biodiversity (*Climate Change*, 2020). Plots one and two were set as the control, while plots three and four were warmed by 5°C in the growing season (*Climate Change*, 2020). Lastly, plots five and six were similarly warmed by 5°C in the growing season, but had snow removed during the winter season to induce soil freezing (*Climate Change*, 2020). As shown in Figure 2, it is clear that the condition warmed by 5°C in the growing season demonstrated a net increase of photosynthesis over the period from 2015-2017 (*Climate Change*, 2020). Templer’s experimental data further supports the proportional relationship between photosynthetic rates and temperature. The condition warmed by 5°C in the growing season with snow removed during winter demonstrated different rates of photosynthesis over the three-year period (*Climate Change*, 2020) (Figure 2). A blanket of snow insulates the plants and protects them from frozen soil and damage to its delicate roots. Plants experienced significant fluctuations in temperature without a protective layer of snow under the experimental condition of snow removal. However in Templer’s experiment, the role of the snow layer on the effect of photosynthesis rate is not clear and more data is needed.

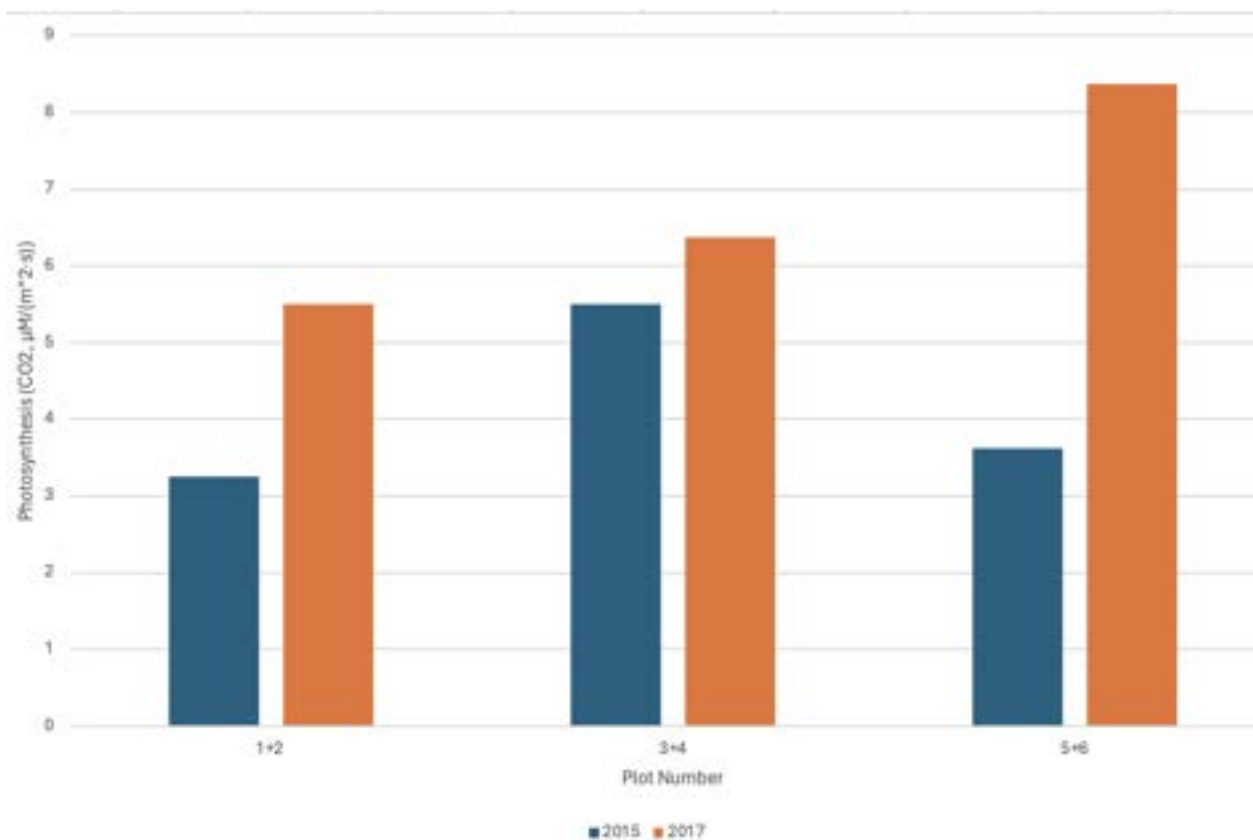


Figure 2: Graph representing the relationship between photosynthesis measured in carbon dioxide ($\mu\text{M}/(\text{m}^2 \cdot \text{s})$) and three different experimental conditions from the year 2015 to 2017.

Plots one and two were set as the control, plots three and four were warmed by 5°C in the growing season, and plots five and six were similarly warmed by 5°C in the growing season, but also had snow removed during the winter season to induce soil freezing.

Discussion

Theoretically, increased atmospheric carbon dioxide leads to higher rates of photosynthesis in plants through the RuBP molecule and the enzyme Rubisco in photosynthesis. Though Rubisco helps catalyze the carboxylation of RuBP, which is necessary for absorbed carbon dioxide fixation, the enzyme also uses oxygen as a substrate to oxygenate RuBP in a process known as photorespiration (Makino and Mae, 1999). Since the carboxylation reaction of RuBP is unsaturated at the current atmosphere levels of carbon dioxide, it is logical that an increased availability of carbon dioxide will increase the rate of carboxylation and thus photosynthesis (Thompson et al, 2017).

However, though data suggests that higher rates of photosynthesis are correlated with elevated amounts of carbon dioxide, there are limitations to this hypothesis. The degree to how much carbon dioxide can influence the photosynthetic rate of plants is unclear, as the stimulation of photosynthesis by carbon dioxide depends on many other variables such as leaf temperature,

water and nutrient availability, salinity, and soil nutrition (Dusenge et al, 2018). The best temperature range for almost all plants is researched to be in between 10-35°C; and the photosynthetic activity of leaves outside of that range sharply decreases (Tkemaladze et al. 2016). Molecularly, although RuBP and increased amounts of carbon dioxide can lead to higher photosynthetic rates, Rubisco carboxylation rates can limit photosynthesis (Thompson et al, 2018). As internal carbon dioxide levels increase to a certain point within the plant, photosynthesis becomes unable to regenerate the same amounts of RuBP to match this increase in carbon dioxide (Thompson et al, 2018).

Furthermore, under long-term exposure to carbon dioxide, plants may incur a down-regulation of photosynthesis in FACE studies (Thompson, 2018). FACE (free-air carbon dioxide enrichment) experiments allow plants to grow in large scale open air environments to test the impact of carbon dioxide on photosynthetic rates (Thompson, 2018). This down-regulation in FACE studies is an occurrence known as photosynthetic acclimation, which is a change in the photosynthetic efficiency of leaves after significant amounts of exposure to carbon dioxide (Ghildiyal, 2000). One explanation for the cause of photosynthetic acclimation is decreased amounts of nitrogen (N) in leaves. In a study performed on rice plants, an increase of atmospheric carbon dioxide caused a decline in N allocation within the leaf, which subsequently led to a significant reduction in Rubisco and other protein synthesis (Seneweera et al, 2011). Without significant nitrogen to invest in rubisco, the photosynthetic capability of the leaf declined significantly (Thompson et al, 2018). Another explanation for photosynthetic acclimation lies in sugar. The extra carbohydrates produced under elevated amounts of carbon dioxide are capable of causing a down-regulation of photosynthetic gene transcripts and suppressing protein synthesis. This down-regulation process decreases the rate of photosynthesis with a feedback inhibition, where products of photosynthesis repress photosynthesis and lead to photosynthetic acclimation.

However, photosynthetic acclimation does not always negate the positive effects that elevated carbon dioxide has on photosynthesis. For example, a study on white clovers growing just under 660 ppm of carbon dioxide for over 8 years were able to maintain a 37% increase in photosynthesis after observed acclimation (Ainsworth et al., 2003). For reference, in the year 2024, the Earth holds a total of 423.84 ppm of carbon dioxide (Daily CO₂, n.d.). This research suggests that plant growth in response to increased amounts of carbon dioxide is most prominently determined by the magnitude of plant acclimation to the increase in carbon dioxide.

Ultimately, research suggests that the long-term impact of elevated amounts of carbon dioxide on plant photosynthesis is relatively unclear. Results from a FACE experiment in a North Carolina forest showed a significant increase in net primary productivity during the first two years of increased atmospheric carbon dioxide, but later showed that this productivity declined over time (Beedlow et al, 2004). With a variety of changes in the climate including increased temperature, reduced cloud cover, and growing season length, the global net primary production has significantly increased and has led to more carbon sequestration for ecosystems. However, rising levels of carbon dioxide does not appear to have a significant impact on increased

sequestration (Beedlow et al, 2004). A study in Italy found that trees that grew in ecosystems with higher carbon dioxide concentrations didn't achieve greater growth or photosynthetic success in comparison to trees that grew in conditions of lower carbon dioxide concentrations, showing the influence that other important factors such as water availability, salinity, and soil nutrition have on photosynthetic rates (Beedlow et al, 2004).

Though evidence points towards the hypothesis that an increase of carbon dioxide in the environment will lead to greater photosynthetic rates for plants, it is clear that there are many conditions and variables that ultimately determine the true relationship between an organism's carbon dioxide intake in comparison to the concentration of carbon dioxide in the environment. It is important to note that although elevated amounts of carbon dioxide may increase the carbon assimilation rate, it does not automatically mean that plant growth will be increased, as there are many factors that influence this growth dynamic. Therefore, it is important for society as a whole to realize that ecosystems and autotrophic organisms can only do so much in response to the growing temperature changes and climate crises, and that humans must find a way to reduce their carbon footprint or one day the incredible biodiversity on planet Earth may eventually disappear.

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Exploring how Financial Planning, in the Form of Strategic Fundraising and Budgeting, can Lead to Success, using FRC as an Example By George Wang

Financial planning is often overlooked as a mere necessity for managing money on a small scale, individual level, but in reality, it is a powerful tool that can drive the success of organizations. In this study, we will dive into the world of financial planning through the lens of FIRST Robotics Competition (FRC) teams. By focusing on fundraising and budgeting strategies, we aim to uncover the impact of financial planning on organizational success.

Through case studies and a survey of a multitude of district teams, we will highlight the diverse fundraising strategies of these FRC teams. Additionally we will address key considerations such as team expenses and fees, equipment purchases, and sponsorship opportunities to see the success and benefits derived from sound financial management. With this study, we aim to gain valuable insights of budgeting that are applicable beyond just FRC and extend it to gain a deeper understanding of the importance of financial planning in achieving organizational goals as a whole.

As briefly mentioned before, something to note for this is that this study will define the idea of financial planning into two parts: budgeting and fundraising.

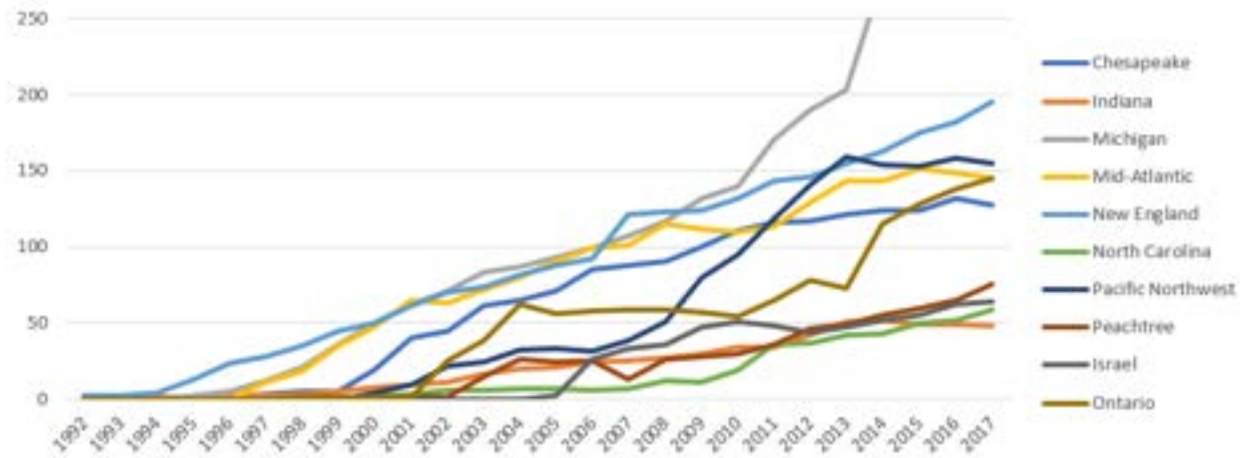
Budgeting is a financial practice that is used by many, including companies, individuals, and governments, in order to effectively manage resources. It includes planning and managing finances so that specific goals can be met within a time frame. The idea of budgeting is very similar to the general definition of financial planning. Expenditures are easily tracked and financial goals are easier to be met with when there is a dedicated team in charge of managing the budget using these practices.

Budgeting wouldn't be possible without fundraising; fundraising is essential for securing the necessary funds. Companies use fundraising in order to support expansion and research, while governments use fundraising in order to secure the funds necessary to drive the construction of infrastructure and create programs that benefit our everyday lives. Additionally, fundraising serves as powerful tools for any movements or personal objectives. Individuals and nonprofits can use online platforms such as GoFundMe or advertise events via the creation of websites.

Fundraising serves several key purposes. First, it provides the essential funds and resources needed for organizations to pursue their objectives. Next, fundraising creates connections between donors, sponsors, and the project holders. This not only fosters a sense of community, but also allows for the project to gain support and recognition. By gaining funds and support, fundraising allows for project-holders to create a positive impact on their communities. In the context of non-profit organizations such as FIRST robotic competitions, fundraising enables success and sustainability of teams, allowing them to participate in competitions, purchase equipment, and provide educational opportunities for those who are interested. Another point to consider is that fundraising is not limited to just monetary donations. Sponsorships often include programs such as mentorships and the supplying of tools and equipment. Specific types

of fundraising such as grants and sponsorships/partnerships will be taken into consideration in the research of this study.

Before delving into how FRC teams represent the ideas of financial planning, it is essential to understand exactly what FIRST is. Founded by inventor Dean Kamen in 1989, FIRST (For Inspiration and Recognition of Science and Technology) is a global organization dedicated to bolster youth interests in STEM. Since its founding, FIRST has evolved significantly, adding on new technologies and expanding to reach broader audiences. Historical innovations to FRC such as swerve drive, an advanced drivetrain mechanism that enables omnidirectional movement, has revolutionized robot design. Nowadays swerve drive appears on the majority of team's robots in a variety of game modes, with older mechanisms such as tank drive being less common. Another recent example of newer innovations are Kraken and NEO vortex motors, two inventions that were prominent in revolutionizing the 2024 season's robot design for many teams. Over the years, FRC has experienced huge growth, with the number of participating teams steadily increasing to encompass thousands of high school students worldwide. It acts as a beacon for collaboration, bringing together those who are passionate about the subject and allowing everybody to work together in a cooperative, competitive environment. FIRST brings together these communities worldwide, including 31 countries such as Brazil, Canada, Turkey, Germany, China, and many others. Shown below is a graph of FRC growth in districts from the start of FRC in 1992 to 2017.



Source: FRC Growth Numbers, Jon Stratis

Collaborating with peers from diverse backgrounds and engaging in hands-on STEM activities also gives students valuable experience that prepares them for their future careers. FRC is a high school-level competition, and teams are sometimes established through clubs. Through these clubs, activities such as project-based learning, competitions, workshops, and outreach programs give students many opportunities to communicate and collaborate with others just like in the real world. Also, FRC serves as a catalyst for increased interest in STEM-related fields, allowing students to grow their STEM passions in an environment that is inclusive and team-oriented. Those who join and find interest in STEM are not just limited to robotics, and in the future are able to branch out into many other fields of interest.

It should also be noted that FIRST isn't solely operated by students, but is also managed through a network of volunteers, sponsors and staff. These individuals are responsible for keeping the event running smoothly each year and setting up the venue for competitions. Something else to note is that many teams include alumni or adult mentors that aid in providing for each club.

In its basics, the objective of FRC is to challenge students to creatively build and program robots that are designed to meet specific needs. Each year, every team is presented with a random game, each requiring unique sets of tasks that a robot needs to complete. Along with this, each team is responsible for gathering the funds, prototyping, and ultimately building the robots to fulfill the challenges on their own. These robots face off with each other in a series of events at a district and/or international level.

The competition features a unique ranking system that serves as the basis of this study. Teams are evaluated based on general performance and ability to complete complex tasks. A more detailed description of the ranking system will be provided later, but for now it should be noted that it recognizes a robots ability to perform in events relative to others.

Events are held at various locations, including universities, convention centers, and schools. Along with this, a livestream of the events are filmed on Twitch at every location, providing easy access for anybody who is willing to watch. At the end of each season, the World Championship is held annually in a predetermined venue, where top teams from around the world gather to compete. As of 2024, this venue is held in Houston, Texas and is set to continue being held here for the next few years.

FRC events follow a consistent schedule throughout each year. During the winter months is when teams typically begin recruiting and training newer members. Returning members take this time to remember to either take on mentor roles or spearhead their own projects in order to improve their own skills. In early January, the official game for the year is announced and teams will begin a variable-duration build season. These seasons are often very competitive and allow for everybody in the team to contribute to a major project. Following this period of time there will be competitions in February. Beginning with several district events, many teams come together in order to compete in the new year's game. Robots who perform better will be able to compete in regional events and district championships as well. This all leads up to the World Championships in mid-April.



Source: First Inspires

One important thing to note is that grants open at around the summertime independent of FRC events. This also includes sponsorship opportunities that provide for non-monetary benefits such as mentoring and training. During this time, teams are given an opportunity to begin acquiring the necessary funds and resources to participate in the competition. The window between when grants open and when the season actually begins is several months long. This gives many teams the opportunity to begin fundraising very early on. Going back to the idea of financial planning, because every team is required to fund their own robot and competition fees, teams will be required to begin planning out their funds and expenditures very early on. Improper planning may result in situations where teams are unable to resupply or even be unable to acquire the necessary resources to even begin building their robot.

Fundraising is essential in FIRST. With the absence of funding, simple and mandatory costs of FIRST (registration, bot parts, travel) are simply impossible.

Registration makes up a hefty portion of FIRST teams' budgets. FIRST is a nonprofit organization, and it is expensive to rent stadiums in hundreds of locations all across the world. These registration costs of FIRST are set at \$6000 for a typical two-district event season, with costs running over \$10,000 for teams who participate in the district championship (DCMP), and over \$15,000 for teams participating in the World Championships (CMP). FIRST helps alleviate this cost for new teams, waiving their registration costs through the new team registration grant.

Travel and hotels also make up a big portion of necessary costs. Competitions are often held far away from where teams originated, especially for National/World Championships. Travel costs vary from team to team, depending on location. Fundraising can provide better accommodations for these traveling teams, improving comfort, giving drivers a psychological advantage in competitions.

Robot parts, arguably the most important cost, often run from \$5000 to \$8,000 for competitive teams. Highest quality components, although expensive, are crucial for performance. However, not every team can afford the top-of-the-line parts. FIRST does help new/starter teams with their bot, providing a baseline "kitbot" that is a great starting point at a substantially lower price that teams can purchase. The kitbot is a pre-designed robot chassis that serves as a starting point for teams competing in FRC, and includes basic standard components such as motors, wheels, and a frame, allowing teams to focus on customizing and adding features to meet the specific requirements of the game challenge; the kitbot varies every year.

With these costs in mind, FRC teams each have their own unique solution to face these challenges. These FRC teams' fundraising strategies, although distinct, have patterns. These patterns create correlations; we will study these overlaps and how they correlate to placement in competitions.

Our final point of interest that we studied during our time at competitions was the responsible management and usage of said funds. Strategic fundraising has its purpose in effectively gathering funds for use. However, its efforts are heavily diminished if responsible usage of said funds are not utilized.

After understanding the context of financial strategies and the event of FRC, let's begin to look at the promises of this study and see how they affect our research.

It is important to clarify that the data presented in this study are sampled specifically from FNC (FIRST North Carolina) teams rather than all of FRC. This distinction is necessary to understand the context of the research findings. While FRC includes the entirety of every robot participating in FIRST robotics, FNC only refers to those participating in competitions organized in the state of North Carolina. Although the teams themselves don't necessarily need to come from North Carolina, the FNC group limits the team population to just those who are nearby to NC. Although these findings may provide for valuable information, it's important to remember that they may not fully represent the entirety of all FRC participants. Some teams were sensitive to sharing their costs, we will only use examples from teams who gave explicit consent for their information to be shared.

As high school students, we had limited resources to be able to contact teams to collect data. We used our connections within FNC (FIRST North Carolina) to collect data primarily from FNC teams. FNC is a major district of FRC, but is not necessarily representative of FRC teams as a whole.

This being said, we were able to collect small amounts of additional data from some teams in other FRC districts to compare with our district's data. We will be referencing/comparing some national/international data throughout this study.

Our research questions were as follows:

- a.* What is the total cost of your main competition robot, excluding travel, registration, or misc expenses?
- b.* What are your most influential sponsors?
- c.* Does your team have a budget management system? If so, what tool do you use?

To better classify our answers to *a*, we break down responses into 4 different cost groups. These cost groups allow us to broadly stereotype costs and correlate them to success and ranking in FNC.

Cost Categories:

\$0 - \$999

\$1000 - \$3999

\$4000 - \$7999

\$8000 +

Established teams' responses were usually given with a range. We asked for estimates; teams usually reuse parts from prior years, and it is difficult to place values on parts that could be worn to different degrees. The large margin of error allows us to place these estimates into a range, adjusting for these possible discrepancies. These cost ranges also allow us to categorize teams into different groups, allowing us to assign stereotypes to groups as a whole.

\$0 - \$999:

Most of the bots in this category are “kitbots”, and relatively simple in parts. With these low costs in parts, the bot will not be as fast, durable, and reliable compared to robots that are more expensive. Based on this assumption, we hypothesize that these bots will have the lowest average placement in competitions.

\$1000 - \$3999:

Teams in this category should be mostly modified kitbots or simple custom bots. These modified kitbots have lower quality parts replaced (mainly motors), raising costs and quality. These robots should be a step up compared to the 0 - \$1000 category, raising overall placement of these teams.

\$4000 - \$7999:

Teams’ robots in this category are especially competitive, with almost none of them using the simple “kitbot”, and deciding to create their own designs, experimenting with the most optimal ideas.

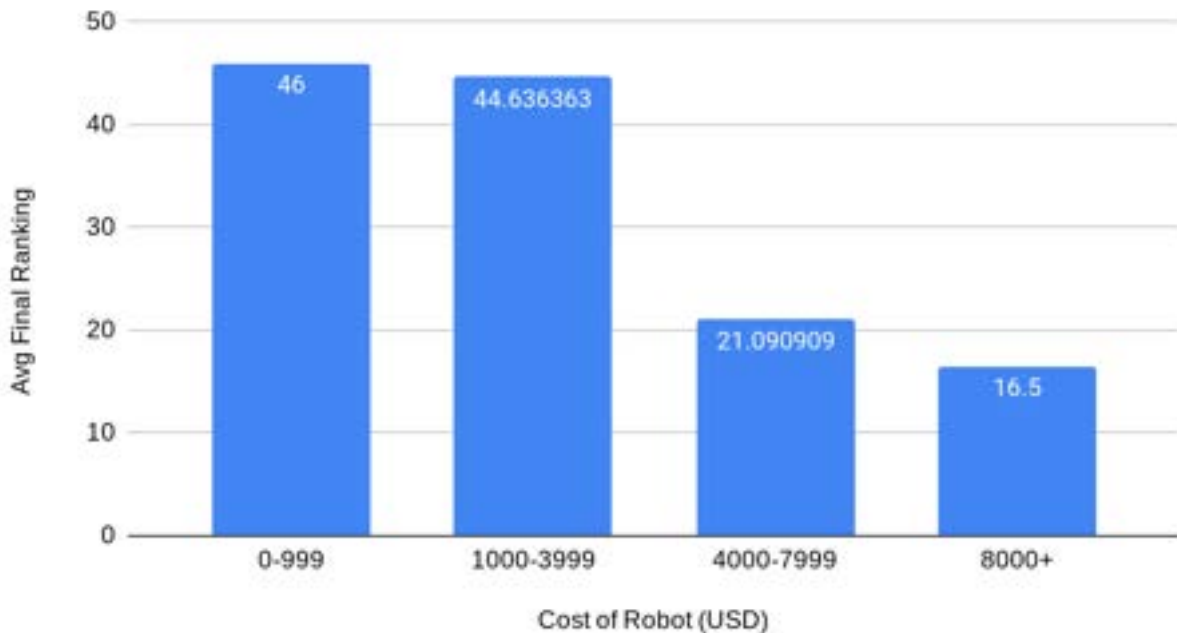
\$8000+

Robots in this category have the peak FRC regulated components. Their speed, fluidity, and accuracy are top of the line.

In general, we hypothesize that there is a proportional relationship between robot costs and overall placement, with higher robot costs leading to better placement. These assumptions are based on the idea that more expensive but quality parts should lead to improved performance.

We define placement as overall ranking within a district. The ranking is determined with the compounding of qualification points and playoff points for the non-CMP (championship) season. The higher the ranking, the more successful a team is (1st is best, etc). Our data is mostly from the FNC district, with 97 teams, so our comparisons and analysis will be mainly based on ranking out of 97. However, our national/international respondents have different sized districts, so we normalize that data to match what their placements would be in a 97-team district.

Average Final Placement vs. Cost of Robot in FNC



Through this study, we confirmed a relationship between cost and average final ranking. This also affirms our hypothesis of how higher cost bots are more likely to place higher.

One area, however, that was inconclusive was the big jump in placement from the \$1000-\$3999 group to the \$4000-\$7999 group. One possible explanation for this would be the fact that plain kitbots that were around \$600-\$900 were rarely used, opting rather to use modified kitbots that would just edge over the price into the \$1000-\$3999 group. This leads to the \$1000-\$3999 group to have an overly large proportion of kitbot-based robots when the \$0-\$999 group was intended to be for these kitbots from starter teams, leading to a lower average placement for that price group.

Although the \$8000+ bots should perform significantly better than the previous price category, we realized that these teams do not necessarily perform better than their cheaper counterparts proportionally, considering how they were sometimes more than twice as expensive. Some limiting factors of these teams could be human error; drivers and operators could be holding the robot's full potential back. This should not be the case, however, raising massive amounts of funds requires a big team with lots of active members. A bigger team should create more opportunities to find talented drivers/operators in your ranks, more so than smaller teams. Coding errors were also a non-monetary factor that was also holding such teams back from our additional questions and observations.

One interesting conclusion we found from the commonality of the \$4000 - \$8000 bots was that it was the perfect sustainable price point for FRC. Robots at this price point remain competitive, allowing them to seem attractive to sponsors, while also leaving room for

improvement and growth. This sharply contrasts to the \$8000+ bots, as those bots do not perform proportionally to justify the steep costs of their bots. This makes the \$8000+ teams not productively efficient, as they require more effort out of their business team to be able to sustain the amount of fundraising they do. Not being productively efficient also explains why the \$8000+ teams were uncommon, more uncommon than the 0 - \$1000 teams. These miniscule and specific aspects of fundraising are crucial to understanding the success of teams.

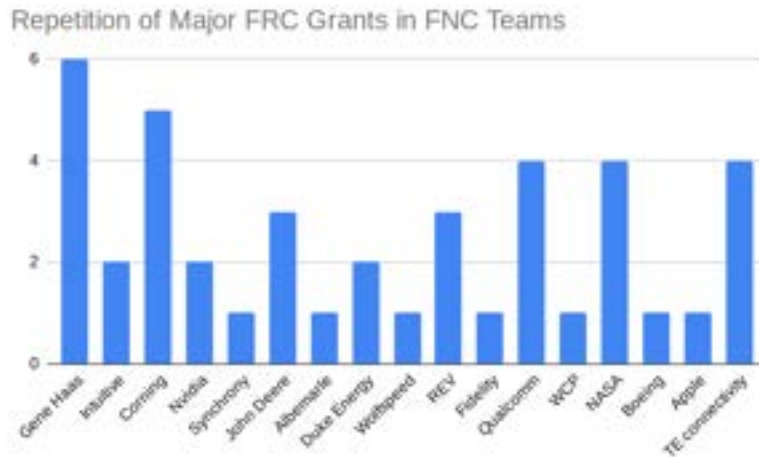
However, one team from Pennsylvania in the Mid Atlantic district, 1391 (The Metal Moose), could prove this wrong. This team had an estimated cost of \$8775, placing 12/127 in their district, normalized to 9/97. An example of a team having a lower average placement than expected in FNC: 6622 Stan Robotix from Quebec had an estimated cost of \$3700, placing 23/40 in their event, normalized to 56/97. The discrepancies of expected values versus real examples can be attributed to different competition levels in different districts.

Fundraising and non-monetary assistance in FRC is unique for every team. There are many ways that external sources can help and improve their selected FRC team(s). Pure monetary-focused grants and corporate partnerships are the main ways that these external sources influence teams. Grants are the more basic of the two; it's purely monetary. Grant amounts can vary, but popular FRC grants usually range from 1000 - 4000\$ dollars. Grant requirements can vary, but companies usually have company values that need to be reflected in the FRC team (diversity, community impact, etc) for the grant to be accepted. Most importantly, although grant-lenders are friendly to incumbent receivers, they are purely one-time transactions that have no guarantee of being received again.

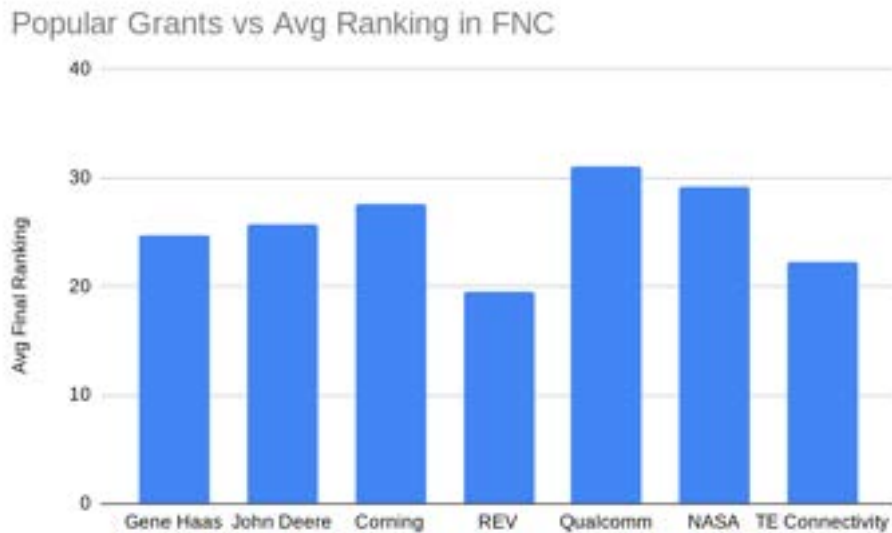
One flaw in our study that is not quite conclusive is how sponsors view FIRST as marketing. Institutions have multitudes of reasons to sponsor FRC teams, and marketing for their company is a major factor. FRC teams have a variety of ways to represent sponsors: logos on robots, shirts, newsletters, etc. With this idea in mind, we can assume that more successful teams get more media exposure, which in turn show off their sponsors' logos more. We can conclude that the advertising space on a successful bot is more valuable than advertising space on an unsuccessful bot, and thus institutions are more likely to sponsor the bots with more success. This idea, if true, creates a positive feedback loop in which successful teams receive more funding from sponsors, utilize the extra money to become even more dominant, gather more sponsors, and so on. This is perhaps why we see the same sponsors among all the most competitive teams, creating monopolistic competition within FRC.

Grants in FRC are usually applied to in the offseason, around fall and/or winter. These grants can come from any institution, local or national, but major lenders to FRC usually offer their grant applications nationally. Major companies have a lot to gain by offering grants to robotics teams; they are personally aiding the development of the next generation of their workers who go into STEM. This reason alone is enough for the FRC grant pool to be flooded with major STEM institutions.

In this study, we researched the various FNC sponsors teams commonly receive, and how specific sponsors correlated to better placement in competitions.



Sorting the most popular grant acceptances, we can create a new graph where we compare these popular grants with final rankings.



Results show that REV is the grant that results in the highest average ranking. Although the Gene Haas grant awards more money than the REV grant, the REV still results in a lower ranking on average. However, if monetary value is the only thing that these grants are providing, how does that correlate with lower placement if REV doesn't provide the most monetary value? We hypothesize that the REV grant correlating with lower placement is just that, a correlation, and not a causation. REV has a rigorous admission process, with only the teams fitting their model the best joining. They also only allow teams with registration submitted to apply for their grants, limiting the amount of teams who can actually apply (counterintuitive if the REV money is supposed to be going towards registration fees). REV is also a major benefactor of FIRST as a whole.

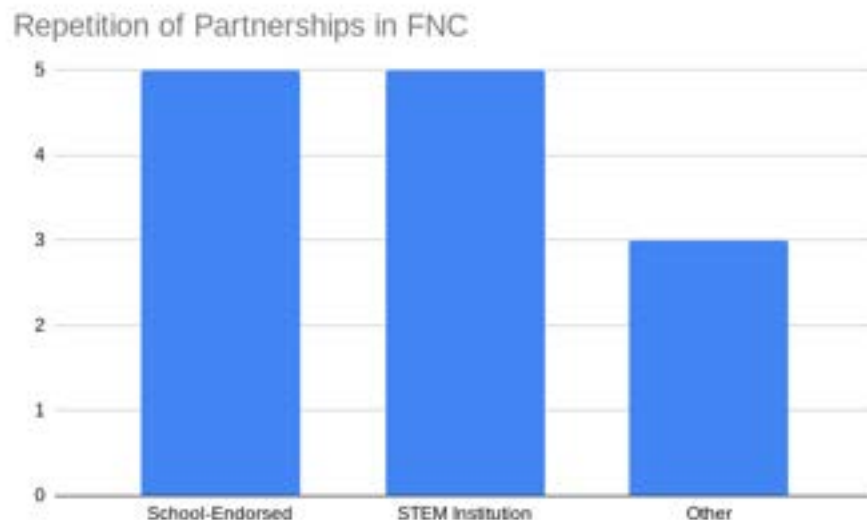
Unlike most of the popular grant companies, REV directly contributes to FIRST, creating swerve modules (gearboxes) for FRC teams to purchase. Swerve modules are expensive, easily the most expensive part of the competition bot. Teams familiar with REV and their swerve modules are more likely to already be established and competitive, with bigger budgets. We think that these money-comfortable teams are more likely to apply and receive the REV grant, resulting in a lower average ranking.

Partnerships, on the other hand, are positive relationships between the FRC team and an institution that lasts for an extended period of time. Institutions in partnerships also tend to donate more money than typical grants, but are also not limited to monetary support. The word “Institution” is broad; it can cover schools, companies, and even nonprofits. Due to these additional benefits that partnerships bring, they are often more rare and limited, with special circumstances constituting their relationships with FRC teams. Due to the rarity of these partnerships, our already limited sample size for the research will be hindered further, only being able to address a few substantial partnerships in FNC.

One possible invaluable benefit of having a backing institution are the special parts that they can make specifically for their FRC teams. Certain partnerships make special motors, swerve modules, etc, that ride the legality line, but provide an immense advantage. Partnerships are not limited to these special components; they can also provide discounts to common robot parts (metal, gears, nuts, etc) that significantly ease the financial burden, allowing for increased prototyping and experimenting that leads to a more robust robot.

The most invaluable addition that an institution could provide is mentoring. Some partnerships with engineering institutions promote increased relationships between faculty engineers and the FRC team through mentoring, an invaluable way to grow a team’s skills.

In this study, we analyze the types of partnerships in our FNC pool of respondents, as well as how partnerships can impact final rankings.



We then combined School-Endorsed, STEM Institution, and all other partnerships into a single group, and compared it to the rest of our non-partnership sample.



With this study, we confirm the relationship between partnerships and average final ranking. Having a partnership greatly increases teams' competitiveness in events.

Sponsors favor local teams, and are more likely to sponsor local teams. This could distort our collected data to make it not representative of FRC as a whole, because most of our data is from FNC, with most sponsors in FNC. These sponsor types vary from district to district, and our sponsors from FNC are not the same as other districts. For example, the National Air and Space Association (NASA) is a big partnership institution, but FNC has no NASA facilities, decreasing the amount of NASA partnerships available to FNC teams.

With the funds received from fundraising, it is essential that teams are able to responsibly utilize said funds to achieve their maximum potential. In FRC, budgeting is especially important for planning through the competition year. Some costs of the season are obvious, (registration, travel, hotels, bot parts) but some costs are less well known and can creep up on unplanned teams (offseason event preparation and registration, offseason outreach events, offseason projects).

With these benefits of budgeting stated, we hypothesize that budgeting allows for increased funds for improved parts, improving overall placement.

Budgeting is not as impactful as brute-force fundraising. Although budgeting works in tandem with effective fundraising, budgeting still completely relies on fundraising. Brute-force fundraising allows for increased room for error, while fervently budgeting with no funds will result in twiddled thumbs, and a failed season. Budgeting properly will have a focus on the balance of fund distribution; we predict that budgeting will result in minimal funds saved (to be used elsewhere), having less of an impact on a team's financial situation than fundraising.. With

this being said, we expect the results from the budgeting study to be less conclusive than the fundraising study.

From our data collected, we can sort responses into 4 categories to help classify responses and draw conclusions.

Budget Categories:

No Budget

School Managed

Mentor Managed

External source

No Budget:

No budget teams are simple; they are starter teams that don't benefit much from having a budget. Starter teams also tend to be small, and with their limited members, a technical role would be more useful.

School Managed:

Most teams in FRC are based in high schools. Most of these schools are public schools - 501C. If these public schools do not directly support the team monetarily (if the FRC team is a school club), then most of these schools will manage the funds of the robotics team (classified as a club) as per school policy. Even with all of these limitations, surprisingly, this category had the most data. Schools manage the budget but usually give control to the robotics members to spend. This budget management strategy protects against embezzlement and fraudulent activities, as the school directly oversees it. These types of teams come in all shapes and sizes, depending on the size of the school.

Mentor Managed:

These teams are similar to the school managed teams. The mentor oversees the budget, and it is up to the mentors to make sure that everyone is being responsible with the teams' funds. These types of teams also come in all shapes and sizes.

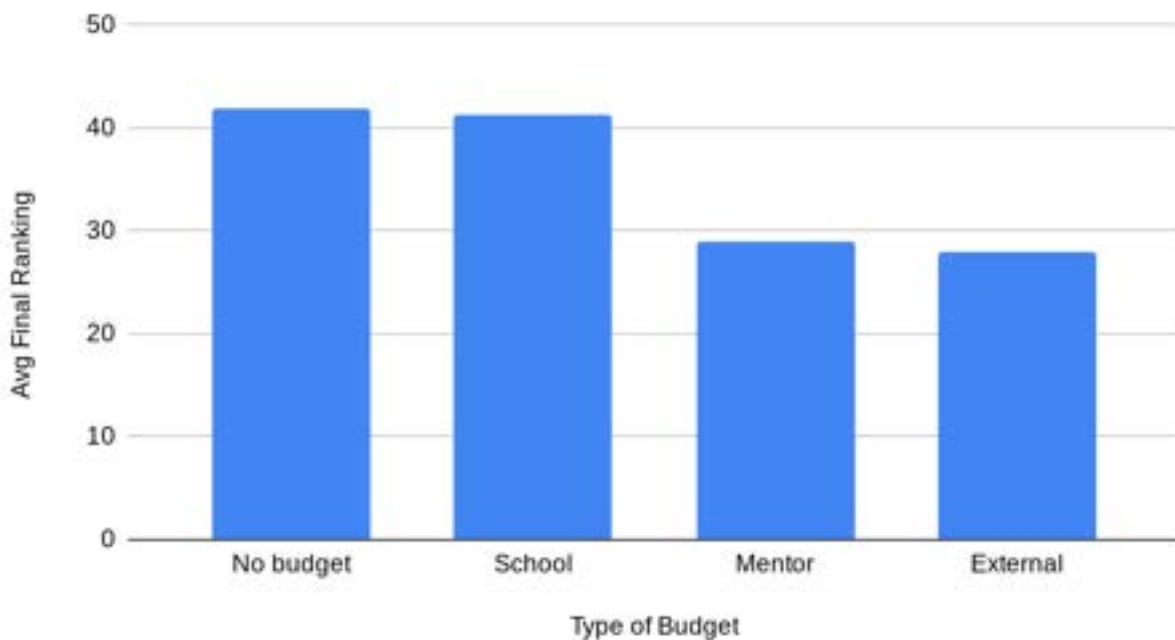
External Source:

Teams that source their budgeting to an external source genuinely care about budgeting and are usually more established and successful. These external sources can vary, with some genuine external sources for management (Ex. 587's NORA), that handle everything and ensures responsible spending, or team members using external tools to manage budget (Ex 4861's YNAB.com). These external tools can help members have a more engaging way to manage their budget, invoking responsibility as well as new skills with team members. However, these benefits come at the cost of increased risk; open access to funds can provoke the greedy nature in humans. These external sourced-budgets were the most rare among our data.

Our Hypotheses:

- a. No budget teams are likely to have the lowest average placement out of the 4 categories because of inefficient spending
- b. School managed teams are likely to have a medium average placement because the school has some idea of what an FRC should portion their costs to be, but less than mentor and external-managed teams.
- c. Mentor managed teams are likely to have a medium to low average placement, mentors are very knowledgeable for budget portioning. However, there are also less competitive teams that have mentors as a way of budget management that could bring down the average for this category.
- d. Externally managed teams are likely to perform the best; external budget management is the most difficult and out-of-the-way solution. Team members know a lot about budget portioning; they also gain valuable skills in the process of financial management.

Impact of Budgeting Strategy on FNC Teams



The budget portion of this study was conclusive. With an average ranking of exactly 28, the external-budget teams were, on average, superior than other budget management strategies studied. The jump from the No budget and School budget teams to the Mentor and External budget teams was expected, mentor and external teams are able to utilize the funds more efficiently. One hypothesis that was inaccurate was our estimation of how much budgeting affected average placement. The jump from the No Budget and School Budget teams to the Mentor and External budget teams was significant, more than we expected. What was also interesting from our studies was how close the No Budget and School Budget groups were, perhaps a point for a future study.

Additionally, we can interpret the same data in a different way. If we instead remove the “No Budget” category and cluster “School Managed” and “Mentor Managed” into a single “Internally Managed” category, we end up with the following categories:

Budget categories:

A. External

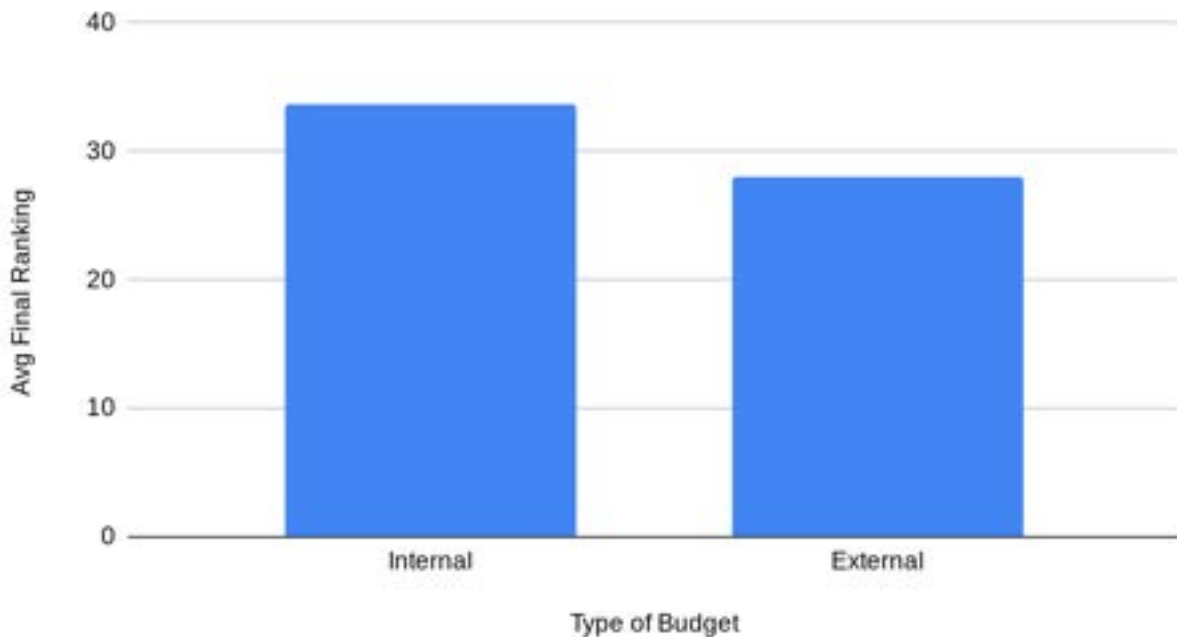
B. Internal (School managed teams + Mentor managed teams)

Shaping our categories into two can help us better compare the two sections, allowing us to draw comparisons and conclusions from them.

We hypothesize that external budget management, when compared to internal budget management, allows the students, who understand their bot the most, make the correct decisions on fund portioning. This increased understanding of the bot and the process will lead to a team with an optimized bot, with necessary sacrifices in the quality of some parts in order to focus on what the team values the most. An optimized bot should lead to increased performance in competitions, showing a relationship between effective budgeting and performance in FRC.

We reorganize the data into two groups below, in a new graph:

Impact of Budgeting Strategy on FRC Teams V2



Through the reorganization of our data, we can clearly show how external budget management has a lower average final ranking, when compared to internal budget management.

However, there are outliers. 568 (Nerds of the North) from Alaska operate with GnuCash, an external budget management source, but their placement in their event was 30/49, normalized to 59/97.

External budget management with students externally can also have a positive psychological impact. Another hypothesis of ours: if the team members are more engaged with the process, then they are more likely to be more involved with other parts of the team, creating passion. This increased passion from the members allows for increased productivity and creativity, allowing the team to improve overall, leading to increased performance in competitions.

In this study, we found that Financial Planning and its components, fundraising and budgeting, when properly utilized, can have a positive impact on FRC teams. Specific fundraising strategies and routes can have an impact on average placement, a measure of success. Different budgeting strategies can also impact average final ranking.

FRC and FIRST institutions as a whole represent an ecosystem that can be seen in the corporate realm. FIRST teams represent independent actors working to secure funding, just like companies. The similarities between FIRST and corporations can allow us to apply these findings to other organizations, to improve operational and productive efficiency. Superior fundraising strategies can ensure that resources are plentiful to support various initiatives, while budgeting properly can ensure proper use of said resources. Adopting these financial planning strategies could improve the success of any organization, not just teams in FRC. Proactivity and the strive of efficiency in the financial realm can help organizations to not only meet expectations, but exceed them to continue growing.

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A comparison of Generative AI against human writers, evaluated by holistic and trait-specific Neural Networks By Boris Lo

ABSTRACT

This paper primarily focuses on the use of modern automated essay scoring, a prevalent topic in the sphere of education AI, by looking at different types of algorithms used to grade student essays. Then, it evaluates the ability of ChatGPT, a form of generative AI against student essays concerning the same prompt. This focus on generative AI is due to the rise in prominence of generative AI such as ChatGPT, which caused contention on the ability of AI and humans in the academic process of essay writing being a focus of AI research. This can be most notably seen due to new AI-driven writing tools, and generative AI plagiarism-detecting tools. Thus, this process involved deep learning techniques, including natural language processing, neural networks and LSTMs. Our study focuses on both holistic and trait-specific scoring for different deep-learning techniques. We then use these models to assess AI-generated essays from the same student prompts. This will be concluded by presenting the effectiveness of our models and the results from the generative AI, ending with a verdict on the ability of generative AI compared to student writers in our study.

Introduction

Overview of AI in education

Education is a process of transferring knowledge, and this was conventionally done by teacher-student interactions within a classroom setting. However, as modern society developed, the development and popularisation of personal computers has allowed individuals and organisations to own and use computers for their own purposes (Campbell-Kelly, 2018). This has led to AI being utilised in education, in areas such as customized teaching and grading (Chen and Chen, 2020), allowing teachers more time to focus on other areas of their pedagogy.

AI serves to enhance teaching methods, approaches, and tools (administrative or educative) in education (UNESCO, 2020). A promising use of AI in education is reviewing and grading students' assignments more effectively and efficiently, allowing educators to achieve greater efficiency in teaching due to decreased administrative burden (Chen and Chen, 2020). AI has a wide range of usages in the education field, and AI technologies regarding education are currently being widely developed.

AI in essay grading

The start of development of AI in essay grading systems dates to 1966 when Ellis B. Page proved on The Phi Delta Kappan that a computer could perform at the level of a human grader (Page and Ellis, 1966). This led to a subsequent period of research on essay grading, leading to the development of a variety of automatic grading systems. Notably, onward from 1990, a multitude of automatic essay grading systems were developed, namely E-Rater (Attali and Burstein, 2016) Intelligent Essay Assessor (Landauer, 2003), Lightside (Mayfield and Rose,

2013), etc. However, a key event in the field of essay grading was the development of generative AI in the 21st century, predominantly open AI's ChatGPT. This led to essay grading becoming an issue of greater focus due to the difficulty in differentiating between the quality of a human writer and an AI.

Motivation

Lack of interpretability

The majority of contemporary work dealing with automatic essay grading focuses on providing an overall score for the essay. However, this singular score is difficult to comprehend and improve their skills from the score (Carlie et al., 2018). A method to target this was proposed by H Nguyen et al.(2016), where he takes existing general-purpose systems, and uses them to score traits in essays. These traits include content, organisation, word choice, and other rubric items. The conclusion was that newer systems, such as the neural network, were reasonably successful in trait scoring (Mathias et al., 2018). However, there still lies a lack of work that evaluates the usage of different modern machine learning models, ranging from simple neural networks to LSTMs, that evaluate essays holistically and trait-specifically, which is what this paper provides.

The relevance of generative AI in essay generation in 2024

One of the main uses of generative AI was to generate essays, and the usage of generative AI cannot be understated. The statistics that the ChatGPT service, the Web front-end for ChatGPT was the fastest-growing service in history to break the 100 million user milestone in January and had 1 billion visits by February 2023 (Herbold et Al., 2023) substantiated the importance of generative AI. Essays have historically been a common medium for educators to assess their students in a wide range of subjects. This is why it was important for us to assess the ability of AI in this area. There has been work and ongoing work being done in assessing AI writing. Recent findings by human researchers on this topic posit that AI could potentially write better than students (Herbold et Al., 2023).

The results prompted a question for us, which was how human-written essays fare against AI-generated essays when evaluated by some of the most effective essay-grading machine-learning techniques detailed in this paper.

Literature review

Holistic Essay Grading

In the last decade, due to the release of Kaggle's Automatic Student Assessment Prize's (ASAP) Automatic Essay Grading (AEG) dataset in 2012, there has been a notable surge in research efforts focused on holistic essay grading.

In recent years, Convolutional Neural Networks(CNN) have been commonly used in essay grading due to the advancement of machine learning techniques. Dong and Zhang (2016) demonstrate the effectiveness of using Neural Networks in this task.

However, another more computationally demanding machine learning technique, Long Short-Term Memory (LSTM), has been used in essay grading in recent years due to the rapid increase in computational power. LSTMs are recurrent neural networks capable of capturing separated relationships in data. They also require significantly more computational power for processing. In our case, the data used to feed the LSTM was 500x more than the data used to feed the holistic models, which may deliver some insight into how resource-intensive LSTMs are. This is because LSTMs need data from every word, in order, while the basic neural network just uses summary statistics of the words. In regards to LSTMs in the essay grading field, Taghipour and Ng [2016] and Tay et al. [2018] were among the first to apply LSTM networks to holistic essay grading, and they achieved promising results in terms of accuracy and consistency.

Trait-specific grading

Recently, contemporary work done in trait-specific essay grading includes essay traits such as organization (Persing et al., 2010), coherence (Somasundaran et al., 2014), and prompt adherence (Persing and Ng, 2014). All the above-mentioned works describe systems for scoring different traits individually.

In our paper, we compare two approaches to score essay traits. We use the enhanced trait scores provided by Mathias and Bhattacharyya (2018). The first set of scores used the traits: Content, Organization, Word Choice, Sentence Fluency and Conventions, which were a set of more general traits. The second set of trait scores was more task-specific and had the trait features of Content, Prompt Adherence, Language, and Narrativity. For each set of trait data, we used two approaches, a simple neural network-based approach and an LSTM-based approach as described. Similar work on LSTMs for essay grading, by Cozma et al (2018), was referenced in the design of the models.

Methodology

Dataset

The dataset we are using consists of ~15,000 essays, and it was released by the Hewlett Foundation when they sponsored the Automated Student Assessment Prize (ASAP) in 2012 on Kaggle. The winning team had a highest kappa score of 0.81407 (Kaggle, 2012), which was calculated by quadratic weight kappa.

In our work which involved both holistic and trait-specific analysis, we used the trait-specific scores provided by Mathias and Bhattacharyya (Mathias et al., 2018) to supplement the data.

We used the ASAP AEG dataset originating from a Kaggle competition from 2012. The essays were written by students ranging from grades 7-10 (12-15). The average word count per prompt varied from 350 to 150 words. Essay prompts varied in type, including areas such as persuasive, narrative, expository and source-dependent writing. The essays were then scored twice by human graders with a clear rubric to follow. Only prompts 7 and 8 have trait scores, so we used the supplemental trait scores provided by Mathias and Bhattacharyya (2018) to enrich the dataset.

The primary method used to handle the data was pandas, and Ast was used to process the locally saved data and enforce its type when reloading for usage. Ast transforms data into the right format by processing Python abstract syntax grammar. The data was then first handled by dropping rows without a score, which was used as test data in the original Kaggle competition.

The essay data was vectorised using a GLoVE 50D vector, which was used as the input data. Glove vectors are trained via an unsupervised learning algorithm for obtaining vector representations for words. We used a set of effective pre-trained GloVE vectors from the Stanford team (Pennington et Al., 2014). The GloVe vectors are a method of mapping the semantic meanings of words onto a plane as vectors. For the neural network, vector addition was used to condense the data as input to the model. To create datasets for different models, the data was split into different categories.

Datasets for different models

Holistic model data

For this category, the data from all 8 prompts were combined, and their overall average score was taken as the prediction field.

Trait-specific dataset

There were 2 sets of trait scores used to assess the prompts, therefore the prompt datasets were split into two groups: prompts 1 and 2 and prompts 3,4,5 and 6. This split was done as these groups all used the same trait scoring. Group 1 scored the traits: content, organisation, word choice, sentence fluency and conventions. Group 2 scored the traits content, prompt adherence, language and narrativity. The datasets with the vectorised essay data were then joined with these two groups to complete the datasets.

Training and validation data

For the holistic model, 10% of the data was reserved for validation data. Regarding trait-specific models, the quantity of data available was less, but 10% was still reserved for validation.

LSTM data

Regarding the LSTM, data was not condensed and was fully preserved, which meant that the data was on average ~350x larger than the basic neural network data. Each word was vectorised using GLoVe and was saved in a 2D array. The essays were then padded using Keras to ensure a uniform length. 20% of the data, or 4000 rows were then used for validation data.

In the trait-specific model, the same process was achieved with a lesser amount of data due to the split for different traits, so around 20% or 1000 rows of data were used for validation.

Models

For our models, we mainly used two types of machine learning techniques. A neural network and an LSTM model. Both neural networks were used for holistic and trait-specific scoring. They were manually tuned for hyperparameters and neural networks generally required more epochs than LSTMs. We will explain each model in depth below.

Neural Network

A neural network attempts to emulate a human brain through the usage of neurons capable of storing the values 1 or 0. Neural networks are formed through layers of these neurons being joined together, and the key layers required are the input and output layers, which correspond to the dimensions of the data, as shown in Figure 1. Between the input and output layers, there may exist hidden layers that help facilitate more complex connections between the data. Neural networks are trained using large volumes of data, and an optimisation algorithm is used to tune the parameters to increase the model's accuracy.

Our neural networks consist of three layers, and the input and hidden layers generally follow the ratio of 3:2, which performed better than other configurations tested. Our input and hidden layers used a ReLU activation function, and the output layer used a linear activation function due to the regressive nature of our prediction. Epoch numbers varied based on each trait, but they were tuned to maximise the accuracy. We did try different activation functions, but they all performed slightly worse.

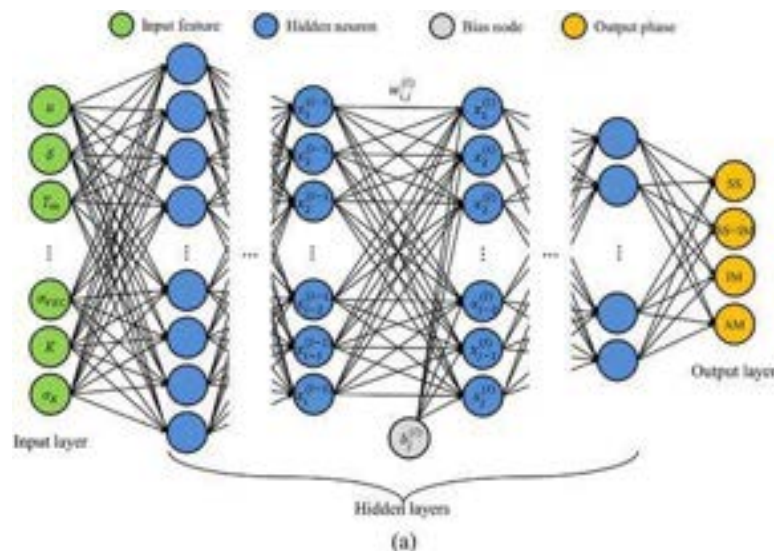


Figure 1. Neural Network Architecture Diagram (Lee, 2020). This diagram demonstrates the inner workings of a Neural Network. For this study, we used a three-layer Neural Network.

Long Short-Term Memory (LSTM)

An LSTM is a type of Recurrent Neural Network, that uses a feedback loop to unroll a network to work well with different amounts of sequential data, as shown in Figure 2. LSTMs perform better than basic Recurrent Neural Networks due it being designed to avoid gradient-related problems. This is why when compared to Vanilla Recurrent Neural Networks, it is found that LSTMs are easier to train because the gradient does not become too large or too small for gradient descent. The design change for LSTMs is that instead of using the same feedback loop connection for events that happened long ago and recent events. LSTMs use two separate paths, one for long-term memories, and one for short-term memories. LSTMs use the sigmoid activation function and Tanh activation functions. The Sigmoid function takes any x-axis coordinate and transforms it into a y-value between 0 and 1. The Tanh/Hyperbolic Tangent function turns any x coordinate into a y coordinate between 1 and -1. LSTMs can be understood by splitting them into 4 stages.

1. The forget gate: determines what part of long-term memory will be remembered.
2. Input gate: determines how to update long-term memory, by combining the value of short-term memory retained with the long-term memory.
3. Output gate stage 1: Updates the short-term memory, starting with new Long-term memory as input to Tanh activation function, and the output represents the potential short-term memory
4. Output gate stage 2: Determines the percentage of the long-term memory to remember using the Sigmoid activation function. Returns the new short-term memory and the output of the entire LSTM unit.

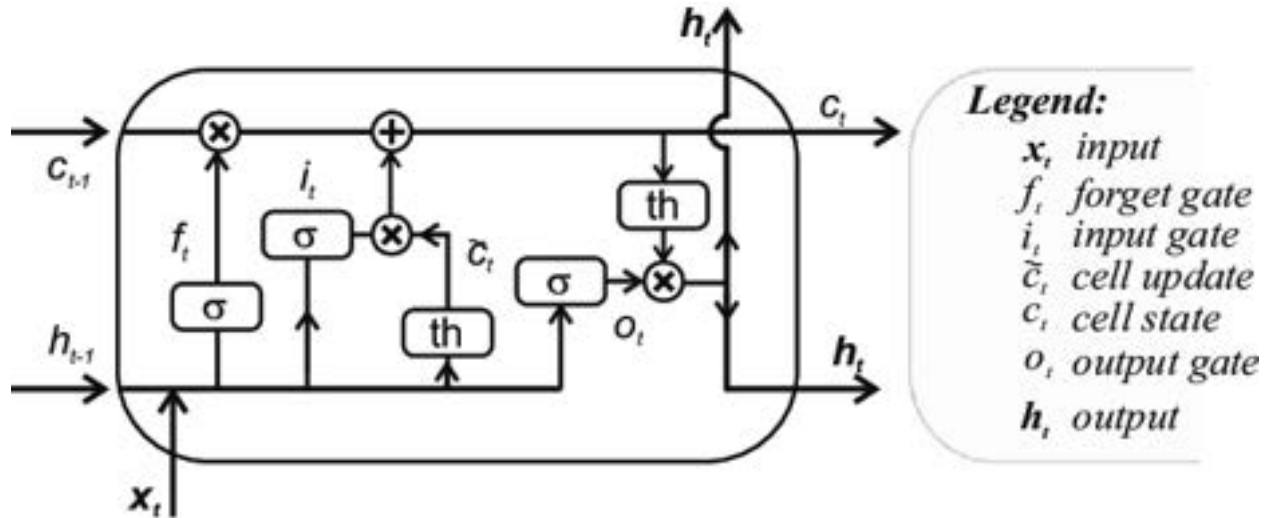


Figure 2. LSTM cell diagram (Hrnjica, 2019). The schematic shown demonstrates the function of a LSTM unit along with helpful labels corresponding to aforementioned description of LSTM functioning.

Results

Overall, our models were successful, as they outperformed or performed to standard to other essay-grading models mentioned in other papers in the recent decade(Kaggle, 2012).

We used two mainstream scoring methods, MAE, known as Mean Squared Error, measures the average magnitude of the errors when compared against correct predictions. Quadratic Weight Kappa, abbreviated as Kappa or QWC is a score that considers other factors such as the closeness of predictions when scoring, and ranges from -1 to 1, signifying a negative correlation, to random correlation, and perfect correlation. This score considers precision and consistency which is why it is favoured in the field of essay grading. Table 1 below explains the range of kappa scores.

Table 1. Table explaining the significance of relevant Quadratic Weighted Kappa Score ranges (Abraham and Nair, 2019).

Range of Quadratic Weighted Kappa	Agreement
Negative	Poor/Negative correlation
0.01-0.20	Slight Agreement
0.21-0.40	Fair Agreement
0.41-0.60	Moderate Agreement

0.61-0.80	Substantial Agreement
0.81-1	Near Perfect Agreement

Basic Neural Network Results

Our Holistic Neural Network performed well concerning MAE read from Table 2, which was an average of 9%, which meant that scores were on average one point off. However, when evaluated against Quadratic Weighted Kappa, scores were much lower. This was likely due to the variety of essays, and the fact that a vector average was fed into the neural network for scoring, which likely inhibited the ability of the Neural Network to conform to a specific type of essay and return a result based only on the words used, overlooking word order and other textual features. These problems were tackled with the LSTM. Nevertheless, the Neural Networks performed well in its task of providing a holistic score for a diverse range of essays.

Regarding traits, MAE increased to 20% of the maximum score, which was around half a point as the maximum score for traits was 3. Quadratic Weighted Kappa performed slightly better than the holistic model, which was surprising because the output layer had more complexity than the holistic model. This was potentially due to trait scores correlating with word choices in the essay, which is an investigation for another day.

Table 2. Table of average model results. Averages were obtained by running models ten times and averaging and rounded to the nearest integer. Average MAE was calculated by MAE divided by maximum score, subsequently multiplied by 100.

Model	Average Kappa Score	Average MAE in %
Holistic NN	0.47	9%
Holistic LSTM	0.92	15%
Trait-Specific NN	0.52	20%
Trait-Specific LSTM	0.63	19%

LSTM results

Our Holistic LSTM results were exceptional, outperforming the best result from the Hewlett Foundation Kaggle Competition in regards to Quadratic Weighted Kappa, which scored 0.814 (Kaggle, 2012), (Nguyen, 2016).

Trait specifically, the LSTM achieved a substantial agreement, with a lower score than the holistic LSTM. This was likely due to the increase in complexity of the output layer, and the MAE and Kappa scores are still satisfactory.

ChatGPT performance

To generate essays for grading, the same prompts given to students were used, with the average word count of student responses used as guidance for the length of essays. 50 essays for the two prompts tested were generated for each GPT model. These essays were then assessed by the aforementioned machine-learning models trained using student essay data. This sets the assessment methodology apart from mainstream grading, which typically uses human examiners to assess essays. The methodology removes human bias and simultaneously provides insight into the closeness of ChatGPT essays to human ones, due to the models being trained on human essays, therefore conforming itself to assess ChatGPT essays with human essays as reference.

We found ChatGPT-generated essays to be more mechanical, and sometimes more convoluted than human-written ones. GPT4 appear to have a better grasp of the question and can respond more logically than GPT3. However, both models lack personal examples when writing, something plentiful in human-written essays that greatly aid in conveying the writer's ideas. Furthermore, ChatGPT lacks nuanced opinions, and its arguments, in essence, are very general and common points, evidencing a lack of personal insight. Therefore, I believed that the student-written essays, mainly written by 15-16-year-old grade 10 students were better than the GPT-generated ones and were more entertaining to read.

Scores computed using our trained models

Neural Network results

The scores computed by the neural network shown in Table 3 were initially surprising, as GPT3.5 outperforms GPT4. However, upon quantitative analysis of the essays, we can explain this from a limitation of the neural networks. This limitation is that our neural network is dependent on the word vector averages. Thus, due to GPT3.5 using a substantial amount of often redundant complex vocabulary likely influenced the average vectors to appear at a high level. However, due to the often inappropriate use of vocabulary, the low trait scores are low, as the trait scores may be associated with logical transition words that GPT3.5 minimally uses. GPT4, on the other hand, used vocabulary more conservatively, and in a more human-like manner, which explains why it scored lower on the overall score that substantially considers vocabulary and scored much higher on trait scores involving the correct use of vocabulary and transitional words or phrases.

Table 3. Table of essay scoring results when graded by the basic Neural Network. Overall scores for GPT were computed by running them through trained models 10 times and computing the

average, rounded to two decimal places excluding the GPT3.5 trait scores due to them being too low.

Score Type	Student Score	GPT3.5 Score	GPT4 Score
Overall Score	6.80	4.75	3.32
Content Score	1.57	0.006	0.46
Prompt Adherence Score	1.59	0.013	0.35
Language Score	1.71	0.008	0.47
Narrativity	1.66	0.014	0.40
Average Trait Score	1.63	0.01	0.42

Overall scores for GPT were computed by running them through trained models 10 times and computing the average, rounded to two decimal places except the GPT3.5 trait scores due to them being too low.

LSTM results

With the LSTM, results remained marginally surprising due to GPT4 failing to achieve 2 points below student scores. The explanation for this is likely because the LSTM was trained on student data, allowing it to consider individual words and overall arraignment. Therefore, it assigns high grades to essays that conform to high-scoring student essays. GPT-generated essays lack the use of student-similar vocabulary and generally do not follow the structural habits of student writing, such as utilising relevant real-world examples. Essays are also less concise, and vocabulary use is less apt compared to students, providing another reason for the low score. GPT3.5 performs worse than GPT4 likely due a weaker reasoning and superfluous diction, which the LSTM takes into account when grading.

However as shown by Table 4, GPT4 was notably graded highly in trait scores, performing better than GPT3.5 and nearing the level of student results. This was likely due to GPT4 having a more nuanced and comprehensive understanding of writing than GPT3.5, allowing it to develop logical arguments similar to the style of students in the format of developing and explaining points with examples. However, it still lacks in the regard of utilising real-world, anecdotal evidence that students use, likely due to a current limitation of GPT being a Large Language Model.

Table 4. Table of essay scoring results when graded by the LSTM. Overall scores for GPT were computed by running them through trained models 10 times and computing the average, rounded to two decimal places.

Score Type	Student Score	GPT3.5 Score	GPT4 Score
Overall Score	6.8	4.10	4.58
Content Score	1.57	0.94	1.57
Prompt Adherence Score	1.59	0.86	1.51
Language Score	1.71	1.01	1.62
Narrativity	1.66	0.98	1.55
Average Trait Score	1.63	0.95	1.57

Essay samples

To provide further insight into the score explanations above, below are extracts from student-written and GPT-written essays from the same prompt complemented with qualitative analysis.

Human writer

Moreover, as a student, computers are a crucial element that allows me to get my work done. without guidance from schools, teachers, or parents. Without computers, it wouldn't be possible for me to reach my full potential in assignments. How could a student be so certain their grammar is perfect on their homework without asking a teacher? There is a way. It is called a grammar-checking tool. However, the only way to access this is through a computer with applications like Grammarly that allows you to check your spelling, grammar, and punctuation with just a click of your mouse. Computers are an essential learning tool for the school system today.

Not only are computers used to educate, but they are helpful in the real world. Many businesses rely on the work of Computers entirely. The owner of the local supermarket, a local business said that In our job, we continuously work with lots of information. this wouldn't be possible without the effort of our typist on the computer. Our president said that businesses and companies around the nation are relying on the advances in technology, so why change anything? We should continue to progress in this growth. 50% of businesses in my neighbourhood say they would have to close down. If not for so many businesses using computers, our economy would drop.”

Figure 3. Human written score 12 essay (Highest score) extract, Lightly edited to improve readability.

This extract demonstrates a heightened awareness of the audience, as the writer discusses the “local neighbourhood”, targeting her audience. Furthermore, the writer logically develops their argument and uses specific real-world examples such as the “typist” for reasoning. However, the human writer(13-14 years old) has weaker organisation than GPT4 and demonstrates a weaker vocabulary when compared to GPT.

GPT3.5

“Moreover, computers serve as windows to the world, offering unparalleled opportunities for learning and exploration. With just a few clicks, individuals can immerse themselves in cultures, languages, and perspectives from across the globe. This exposure fosters cultural understanding and empathy, ultimately contributing to a more interconnected and harmonious society.

Additionally, the advent of online communication platforms has revolutionized the way we connect with others. Whether it's rekindling old friendships or forging new ones with like-minded individuals, the internet fosters a sense of community that transcends geographical boundaries. In an age where isolation and loneliness are prevalent concerns, the ability to form meaningful relationships online can be a lifeline for many.”

Figure 4. GPT3.5 generated essay. Score 5 when assessed by Neural Network, Score 6 when assessed by LSTM

GPT3.5 demonstrated complex lexical features, and exhibited reasonable organisational skills. However, it suffers in reasoning and development of the argument. Additionally, no specific examples are used, and only general examples such as “online communication platforms” are utilised to elucidate the argument.

GPT4

“Moreover, computers have been instrumental in enhancing our hand-eye coordination through various interactive applications and games. This skill is not only beneficial for children in their developmental stages but also for adults, as it can improve reflexes and spatial awareness. Such cognitive benefits are a testament to the positive impact of computers on our mental acuity.

The argument that computers distance us from nature and physical activities is a matter of personal choice rather than an inherent flaw of technology. Computers do not inherently discourage outdoor activities; rather, they offer tools for planning and enhancing our interaction with the natural world. Applications that track hiking trails, identify flora and fauna, or encourage outdoor fitness activities are perfect examples of how technology can inspire a deeper connection with nature.”

Figure 5. GPT4 generated essay. Score 6 when assessed by Neural Network, Score 8 when assessed by LSTM.

GPT4 clearly performed better than GPT3.5, especially in reasoning. It utilises reasonably specific examples such as “applications that track hiking trails” to support its arguments. It maintains a high level of vocabulary and demonstrates an effective and clear organisational structure that supports its point development. It clearly outperforms GPT3.5, however, it lacks the specificity and real-world element that human writers display, as well as the audience awareness of a human writer.

Concluding remarks

Limitations

The limitation of this study was the variety of the data. Our data was mainly from students in high school, and having a range of training essays from elementary to PhD level may have allowed our models to grade more universally instead of establishing the target as high school student essays. Furthermore, our data is from a decade ago, and the average level of

student writers may have changed. Moreover, our models do not take spelling into account, which may also be an important criterion in essay grading.

Future work

Future work should look into training a greater variety of Machine Learning techniques or Neural Networks for grading essays. Furthermore, the work should also experiment with a more diverse range of essays. GPT and other generative AI continue to develop daily, and their ability in essay writing is an important indicator of their progress. This is why future work should continue using objective machine-learning techniques to grade AI-generated essays as generative AI develops.

Conclusion

In conclusion, in our study, we successfully trained modern Neural Networks for essay grading based on the large ASAP essay dataset, which was supplemented by trait scores. Our neural networks graded both holistically and trait-specifically, supplementing the literature. From our findings when comparing against human writers, we found that the trained Neural Networks generally graded GPT-generated essays lower than the student samples. Furthermore, we discovered that the simple neural network grades GPT3.5 higher than GPT4, whilst it was the opposite using the better-performing LSTM.

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Alaskan Judicial System: To Understand a Gap in Knowledge By Daniel Wong

Abstract

This study examines the interplay between Alaska's geographic, demographic, and economic landscape and its legal outcomes, focusing on data collection challenges. To explore issues impacting data collection and legal outcomes, the paper synthesizes a variety of surveys that were conducted across geographically isolated towns and among socioeconomically diverse groups and data collected by government bureaus and organizations. Analysis indicates that a correlation exists between a lack of standardized data, specific legal outcomes, and factors such as geographic isolation and socioeconomic disparities. These factors contribute to difficulties in discerning consistent legal trends, exacerbated by overburdened court systems and monetary influences. The results from these sources indicate the need for reforms to ensure impartial data collection and legal outcomes. Addressing economic disparities is particularly critical, as they perpetuate unequal access to legal assistance.

Introduction

Alaska, a non-contiguous U.S. state situated on the northwest edge of North America, has recently garnered national attention due to a concerning surge in crime (Alaska Public). Ranking second highest in violent crime rates among the fifty states, trailing only New Mexico, Alaska reports an average of 758.9 violent crimes per 100,000 individuals—nearly doubling the national average of 380 (“Which”). With the high crime rates and more than 92,000 legal cases processed in 2023 alone, it is imperative to explore and establish why the rates have remained elevated (Beacon, “Alaska’s”). The collection of standardized data to diagnose and establish a trend in crime rates has been difficult and insufficient and has therefore influenced the result of the data collected.

This review explores the increasingly complex issues that make it difficult to accurately observe trends and uninfluenced outcomes in the judicial system in Alaska. The paper discusses difficulties including the state's immense geographic size, the diversity of its communities and their unique legal traditions, resource constraints, intricate legal frameworks, problems with data gathering, sociological influences, and trust-related issues. By synthesizing peer-reviewed articles and representative statistics, emerging patterns and inconsistencies demonstrate a flaw in the current Alaskan political and economic landscape. The three key components that drive the lack of standardized data include geographical landscape, a lack of standardized subjects, and socio-economic factors. Ultimately, it is imperative to establish a sustainable framework for future court cases and data collection.

History

The historical context of Alaska's socioeconomic and geographical landscape lays the foundation for why Alaska faces challenges with data collection and equitable legal outcomes. Alaska's historical background, including its indigenous heritage, colonization, economic shifts,

and policy decisions, exemplifies a lack of reliable and conclusive results from analysis in the legal system. Alaska's indigenous heritage has long been established. In prior years, discrimination and inequitable treatment of Native populations had created instability and a dividing perspective within Alaska. Additionally, the economic shifts in the international landscape have altered Alaska's profitability and their ability to maintain strong economic growth in recent years. Finally, policy decisions that favor specific demographics have also been inserted, changed, and removed in prior years, highlighting the instability in Alaska's jurisdiction. In 1867, Alaska, the largest state ever admitted to the Union, was acquired by the United States. Subsequently, the proliferation of unfamiliar diseases led to the decline of the Indigenous population. Even though the native population plummeted during the 1940s, 16% of Alaska's population is composed of American Indians—the highest of any state in the United States (U.S. Census Bureau). Thus, Native law has played an influential role in the legislative systems, impacting rulings, laws, and policies.

Geography

In terms of its physical geography Alaska spans over 663,268 square miles and boasts diverse habitats that include tundra, forests, glaciers, mountains, and coastline; moreover, this massive state is divisible into five distinct geographic regions: the Arctic Coastal Plain, Brooks Range, Interior Plains and Plateaus, Alaska Range, and the Aleutian Islands (Hayes).

Due to its geographical diversity, diverse population, and federal, state, and tribal jurisdictions, Alaska faces distinct challenges in law enforcement, legal representation, and access to justice. Alaska's legal landscape is characterized by its complex cultural diversity, encompassing indigenous communities, each with its own cultural norms and legal traditions. The system integrates various laws, such as federal laws, Alaska state laws, and tribal laws, leading to a complex interplay of jurisdictional authorities.



Figure 1: Court Locations in Alaska 2022 (“Administrative”)

The establishment of courthouses across the four districts in Alaska has hampered the availability and access to legal aid. According to an annual report published by the Alaska Court System Administration, there are only 40 individual superior and district courts in the 4 Alaskan judicial districts⁶ (“Administrative”). Considering Alaska's population is 733,390 individuals, there are, on average, more than 18,000 individuals per available courthouse, highlighting the scarcity of local courts. In comparison, Texas boasts 2,800 individual superior and district courts (Anson). Texas has, on average, one courthouse per 1070 individuals, with a population of roughly 30,029,572 individuals.⁷

For example, during the COVID-19 pandemic in 2021, Kake⁸, a small village of approximately 500 people situated on the northwest coast of Kupreanof Island in the Alexander Archipelago in southeastern Alaska, sought an emergency subsistence use permit. This permit is available to Alaskan residents for subsistence hunting when there is not enough game for a general hunting season. However, the request faced initial denial, brief approval, and then subsequent delay due to a lawsuit from the state government (Sullivan). While the pandemic played a pivotal role in the government's decision to deny the emergency subsistence, the geographical hurdles, specifically the physical locations of the courts, and the lack of legal

⁶ The count of courthouses (400) in Alaska was updated in 2022

⁷ The statistic on Texas (2,800) was provided in 2013. The population used to calculate courts per capita was provided in an up-to-date report for both states. As of July 1, 2022, the population of Alaska is roughly 733,391 individuals (“U.S., Alaska”). As of July 1, 2022, the population of Texas is 30,029,572 individuals (“U.S., Texas”).

⁸ The city has a total area of 13.51 square miles (34.98 km²), of which 7.67 square miles (19.87 km²) is land and 5.83 square miles (15.11 km²) is water. As of 2020, the population of Kake was 543 individuals.

representation significantly hindered the ability of the tribal Alaskan community to advocate for itself in a time of need. In the case of Kake, the geographical landscape made it difficult to transport resources in times of desperation. Thus, the government saw that as an opportunity to refute assistance in court. Though the decision would later be revoked, it displays the key role geographical isolation plays in influencing the collection of standardized information.⁹

According to an article published by PBS, overburdened state courts handle most criminal cases. Both the Alaskan Native Tribes and corporations concur that the legislative system is outdated and fails to acknowledge tribal sovereignty (Sy, et al.). Due to the urban landscape of Alaska and the low concentration of populated towns, there is insufficient funding to reinforce legislative systems and establish modern court locations. The consequences of this resource distribution are unequal and inaccurate representation due to geographical factors. Additionally, during COVID-19, federal, state, and local entities would omit or misclassify American Indian and Alaskan Native populations, resulting in an undercount of the impact of COVID-19 on the Native people (“Best”). This marginalization of inappropriately classified populations led to inaccurate demographic reports in court case data. Ultimately, the collection of standardized data is inhibited since court cases by native populations are often overseen or ignored, skewing the direction and conclusion of data.



Figure 2: Court Locations in Alaska 2022 (“Administrative”)

⁹ Geographical Isolation and Accessibility Theory: Even though Alaska retains its position as one of the 50 states, it remains isolated both geographically and socially. The concept of geographical isolation plays a crucial role in Alaska's socioeconomic landscape as more rural communities face challenges related to transportation, infrastructure, and access to essential services like healthcare and education. The result of this isolation is a lack of standardized legislative systems, legal assistance, higher costs of living, and limited economic development.

Common Trends or Conflicting Results

Geographical isolation and lack of urbanization promote overwhelmed courts and lack of equitable access to legal services for Alaskan citizens.

With the reports given by Alaskan residents, the inadequate number of courts throughout the districts can be attributed to the geographical nature of Alaska. Once again, the landscape of Alaska hinders the collection of standardized data.

The location of courthouses and population across regions of Alaska exemplify how more population dense areas have better access to legal representation while more rural regions lack adequate legal representation. Furthermore, the overwhelming numbers of people per courthouse had fostered an inundated and understaffed environment resulting in a lack of consistency and fluidity in the ruling. In a court study, it was determined that judges were more lenient in ruling after breaks or vacations with many judges admitting that emotion and mood did play a role in the final ruling (Bryant). With judges being overworked in many of the Alaskan court cases, inconsistent court rulings ultimately result from unstable environmental situations. The combination of legal aid being more readily available to populations in specific areas and the overwhelmed courthouses in Alaska has resulted in unstandardized data. Individuals who do not live near courthouses have less access to legal aid and the courthouses that currently handle cases may not rule impartially. The legislative data is ultimately an inadequate representation of the actual state of Alaska. Evidently, the geographical placement of courthouses and the overwhelmed nature of existing courthouses influence the collection of standardized data.

Jurisdictional conflict

Due to the varying classifications of law across Alaska, the diverse nature of the population has resulted in a lack of uniform ruling. The largest racial/ethnic group in Alaska is White (Non-Hispanic) with 64.1%. The state is also home to a significant population of American Indian and Alaska Native people, who make up 15.7% of the population (“U.S., Alaska”). With one of the highest native populations out of the 50 states, it is evident that a mix of different cultural identities, cities, and communities will continue to reside in Alaska, shifting the lens of standardization for every court case depending on both the community culture and social basis.

In certain more native-populated areas, there are more lenient rulings on hunting and fishing. For example, the legality of specific hunting methods, seasonal restrictions, permissible catch limits, or licensing requirements may vary based on the location or community (“Hunting”). This can lead to conflict with the state and tribal entities due to disagreements in cultural standing. In the case of *Katie John v. Norton*, a 27-year legal battle over Alaskan subsistence rights between state and tribal law emphasized the inconsistency with rulings across Alaska due to the diverse set of laws within the legal system. Katie John, an Ahtna Athabascan Indian, fought for subsistence hunting and fishing rights as her family relied on salmon for sustenance. Because the state of Alaska closed the subsistence fishery near her house for

companies to take hundreds of thousands of salmon for sport and commercial purposes, they had strained her family's food source leading to legal conflict. As the regional court ruled on behalf of state interest, an eventual appeal was made, and the 27-year conflict ended at the Alaska Supreme Court where they ruled in favor of Katie John ("Hunting"). The disagreements between tribal and state laws are exacerbated by the issue. Extending beyond hunting and fishing regulations, *In Re Adoption of E.H. and J.H.*, a 2018 legal case regarding the adoption of children, the contradictory ruling between state and tribal law is exemplified. A couple living in a remote village filed a legal case, arguing that their tribal court adoption should be legally recognized by the state¹⁰. However, the state of Alaska initially refused the tribal court adoption despite tribal recognition ("In"). Even though the Alaskan Court finally ruled in favor of the adoptive parents, the initial opposition to the tribal ruling underscores the lack of agreement between tribal and state law.

In addition to differences between state law and tribal law there also exists conflict between federal and state law. For example, in Public Law 280 (PL 280) passed by Congress in 1953, the federal government gave six states, including Alaska, criminal jurisdiction over tribal members (NIOJ). Afterward, however, the Alaska Supreme Court reversed its prior decisions in 2001 and held that "Alaska Native tribes are sovereign powers under federal law" (AFNA). Throughout the contrast between native and federal law, PL280 was originally enacted by the federal government in hopes of balancing laws between native federal rulings. Though the ruling encompassed Nebraska, Minnesota, California, Oregon, and Wisconsin in addition to Alaska, the primary area of focus was on the impact of Alaskan tribal jurisdiction ("What Is").

For example, the recreational use of marijuana, although legal under Alaska state law, remains illegal under federal law (Henderson) exemplifying the power dynamic between rulings. In *Ravin v. State*, a 1975 court case between Robin C Ravin, who claimed that he could possess and use marijuana due to federal ruling, and Alaska, which had not yet legalized the possession or use of marijuana¹¹, ensued. Ultimately, the ruling effectively decriminalizes the possession and use of marijuana within the privacy of one's home in Alaska (Breece); however, the conflict also emphasizes the contradictory ruling and gaps between state and federal law. Additionally, in the Kuskokwim River Case, a territorial disagreement over Alaska's largest subsistence in salmon fishing, the federal government sued Alaska over its rulings, claiming that the rulings had superseded the State's and applied over waters that fell under State jurisdiction ("Alaska State"). In both situations, the play between state and federal law has led to a lack of standardization in

¹⁰ The ethnic identities of the individuals within *Re Adoption of E.H. and J.H.* were not mentioned or documented in the published court cases.

¹¹ With the State rulings against the federals', the marijuana regulation applied to all 4 judicial districts and remains active despite federal disagreements. With the Kuskokwim River case, there remain disputes that, although focused on economic standings, still apply to the ability to exert power between the federal and state governments.

rulings and regulations. These conflicts are further exacerbated due to the lack of data that is applicable across all three respective jurisdictions (e.g. federal, state, and native)¹².

Common Trends

An intricate relationship between tribal, state, and federal law perpetuates the difficulty in synthesizing standardized rulings and cases and using them to corroborate claims.

Because tribal communities and colonial communities have opposing perspectives on rulings, disagreements over rulings and laws in specific regions and courts often surface¹³. Conversely, the conflicting ideologies on certain policies cannot be reversed due to regulations made in accordance with native laws in the state rulings.

Ultimately, the federal laws, when contradicting the states', often lead to further division and lack of accepted data. With disagreements between policies, territory, and rulings, the devaluation of a common and accepted set of laws will continue to persevere.

Comparison

In terms of instability, the concept of geographical isolation and lack of standardization go hand in hand. With geographical isolation, the reduction of available courthouses along with diverse communities leads to inadequate support and access for residents across Alaska; furthermore, the fluctuating equilibrium between native, state, and federal ruling accentuates the issue. Though the varying degrees of cases, classifications, and rulings skew the data, the repetitive power struggle between the three jurisdictions furthers the disparity in relevant data. Frequent changes in ruling make it difficult for courts to rule consistently in addition to different legal systems.

Socioeconomic Factors

Socioeconomic factors have also played a role in making standardized data collection difficult, especially with the current metamorphosing landscape. According to recent studies, there have been significant changes to the economic status of residents; specifically, the median income has lowered compared to previous years. According to the U.S. Census Bureau, the median household income in Alaska in 2020 was about \$77,790; however, in 2015, it was \$1,500 more, at \$79,258. Furthermore, a report by the University of Alaska Center for Economic Development determined that this low economic performance places Alaska at or near the bottom of all states and D.C. for the period from 2015 to 2021, as well as the pandemic-affected

¹² Between the native and federal laws, the concept of a power struggle influences the reduction in standardization. With the native laws acting following native ideology, beliefs, and culture, there cannot be a definitive ruling due to inconsistency.

¹³ Colonial and Indigenous Perspectives: The dichotomy between colonial and Indigenous Perspectives plays a pivotal role in fuelling the lack of standardization in the Alaskan legislative system. Contrasting perspectives on Historical policies, land rights, and cultural practices significantly influence indigenous communities' access to resources and existing socioeconomic disparities.

period from 2020 to the present (“Alaska’s”). One factor behind the lack of economic growth is the lack of economic diversification. In 2021, Alaska was ranked as the state with the highest percentage of total economic contributions by the natural gas and oil industry, generating \$19.4 billion towards the state's GDP with just these two sectors alone (“New”). Alaska’s economy is heavily reliant on the export of natural resources¹⁴. However, with the pandemic, there was a weakened workforce, which may have influenced the current state of the economy. Despite the unemployment rate in Alaska from 8.3% to 4.3% from 2020 to 2023 (“Alaska Unemployment”), Alaska’s unemployment is still comparatively higher than the national average rate of 3.7% (U.S. Census Bureau). Though Alaska’s gross domestic product (GDP) growth was roughly 3.6% in 2023, Alaska still fell behind the national average in the U.S., which placed Alaska at 41st in terms of GDP growth. In 2023, Additionally, despite years of technological progression, Alaska’s economy remains reliant on the extraction of natural resources.¹⁵ Large corporations have often monopolized the extraction process establishing factories and streamlining the extraction of oil, fish, and lumber. While larger corporations within Alaska have expanded, the median household income has decreased, highlighting a growing gap in economic standing between high-ranking corporate figures and the average citizen (fig. 1).

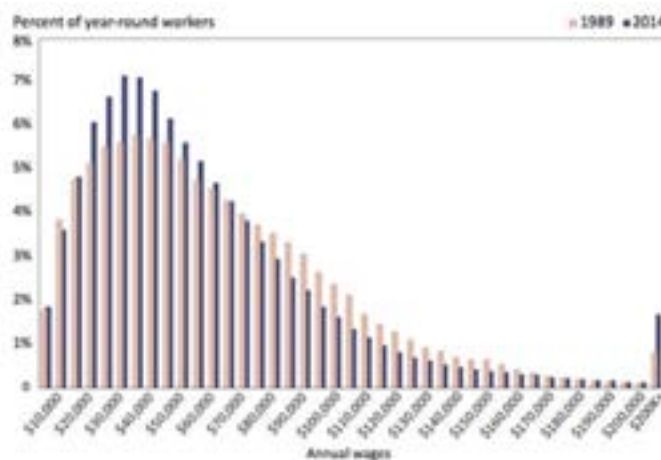


Figure 2: Alaskan Annual wage comparison between 1989 and 2014 (“Sitnews”).

Because of a widening wealth gap, a larger difference in personal financial resource availability presents itself. The gap leads to both unequal access to legal resources and an

¹⁴ Resource Dependency Theory: The dominant influence on Alaska's economy is the extrapolation and export of natural resources including oil, fish, and minerals. The resource dependency theory determines that regions that are overly reliant on one specific industry are more susceptible to economic recessions, market fluctuations, and lack of individualistic economic diversity.

¹⁵ Economic Diversification: The lack of economic resources influences the ability of social classes in seeking legal assistance. Under the economic diversification theory, emphasis on broadening the state’s economic horizon past a single industry encompassing resource extraction could increase sustainable employment opportunities and reduce socioeconomic inequality.

increased risk of inequitable legal representation (Abogado). The inability to pay for legal representation or failing to navigate complex legal processes and failure to present an effective case leading to significant disadvantages compared to an experienced legal counsel that could have been outside the affordability range. Additionally, due to a lack of legal aid services derived from financial restraints, there is a higher risk of negative legal outcomes ranging from asserting rights in a criminal defense case to family law and housing disputes. This in turn disrupts the ability of individuals to present a strong case leading to unfavorable judgments and inadequate protection (Abogado). Though the argument that Pro Bono cases help resolve these financial constraints, in 2018-2019 only 16% of all pro bono cases requested by citizens in Alaska were represented in court (“Pro”).¹⁶

The American Bar Association currently strongly pushes 50 hours of pro bono service for practicing lawyers. In Alaska, there are currently 2,235 active lawyers with a state population of 733,406 documented individuals (“2021”). In California, there are currently 195,000 active lawyers with a state population of 38,965,193 documented individuals (“United”). Thus, the average lawyer-to-people ratio in California is 1:199 while in Alaska the ratio is 1:328. Even accounting for the standard regulation on pro bono work time, it remains evident that the strained resources of Alaska have led to less availability to resolve court cases based on a per capita calculation. This notion exemplifies the reasoning and evidence behind lower legal case collection in Alaska compared to many other states, especially when it comes to pro bono cases which are done regardless of the individual's socioeconomic status.

Overarching Trends

Geographic challenges with the location of courthouses, the unstable economic state, and a diversified population have all played a significant role in the difficulty of deriving data on court cases or legal matters that do not exceed the threshold in terms of being standardized. Repeatedly, in times of economic instability, Alaska has developed an unstable relationship with the lack of standardization between federal, state, and native legislature. This is depicted in the state court hearing regarding subsistence distribution to native communities. Furthermore, court cases furthering the discrepancy between adoption rights for indigenous communities and fishing laws underscore the lack of coordination between perspectives and underrepresentation due to socioeconomic factors and diversity. Beyond economic situations, the diverse interplay between federal, state, and tribal legal systems influences the creation of standardized data.

Alaska is known for its cultural diversity, but this factor has frequently shaped rulings on case classification, thus perpetuating the unstable dynamic of how a standard Alaskan court should rule. Even though other states, such as California and New York, have their fair share of

¹⁶ Social Determinants of Legislature: Being born into a poor situation that cannot be controlled or changed comes as the result of a lack of social mobility. The concept of social determinants of legislature highlights how socioeconomic factors situated in Alaska, including income, education, employment, and living conditions, significantly influence access to representation. In Alaska, disparities in these determinants contribute to legislative inequalities among different communities and thus reduce standardized results that apply to all court and legal cases.

diverse populations, Alaska's indigenous people have a significant influence on the establishment of laws and regulations. Additionally, in terms of geographical prospects, villages, and cities rarely comprise populations with completely aligned cultural and legal standings. Furthermore, the regulations imposed by different forms of government on different parts of the population have ultimately led to instability and diminished legal resources residents have access to.

Conclusion

Alaska is a state with a distinct geographical and demographic situation. For unbiased representation, additional courts across Alaska must be established. The overwhelmed state of the current courts paired with the large distance individuals within certain cities and towns must travel to seek legal representation, make it difficult for certain groups to acquire proper representation. Populations similar to that of the City of Kake, could face similar challenges with legal pushback because of geographical implications. By erecting courts in key areas to provide legal access for populations, impartial legal data that encompasses the entire scope of Alaska can be established.

In the research and statistics provided by the government and civilian reports, the failed appropriate classification of Indigenous populations paired with the general failure of equitable representation of Native populations exemplifies the notion of inaccurate data and inequitable legal representation with marginalized populations. An effort for equitable representation for Native populations and proper standards for demographic classification must be established to mitigate inaccurate legal data and push for impartial legal results.

Additionally, because of the diverse population in Alaska, different legal frameworks have been established to fit certain niches. However, for standardized data to be collected and applicable for all legal proceedings in Alaska, there must be consistent laws established in federal, state, and tribe related cases. A limitation to these laws, however, would be the difficult nature in regulation due to the diverse population and cultural backgrounds that exist in Alaska. Thus, the most probable solution to increase equitable rulings and standardized data collection is altering the economic framework.

In the realm of economics, the key role economic disparities have played is mitigating the number of potential court cases and hindering equitable legal battles. Despite the pro bono aspects being available to individuals, the majority of citizens still do not receive proper legal aid; additionally, pro bono lawyers may not be as effective compared to private legal aid. Beyond the surface scope of legal access, the key issue with Alaska's socioeconomic landscape lies in the fixed economy of Alaska. While the global economy has begun shifting towards the technological sector, Alaska remains focused on resource extraction. Moreover, this focus has driven companies that monopolize the resource sector to gain immense wealth while the average Alaskan citizen remains stagnant. This divide pushes the financial divide amongst the Alaskan population and perpetuates the inequitable legal access that has harmed data collection and influenced results.

By facilitating changes in key areas within Alaska that root out specific issues, such as antiparallel laws, economic disparity, and legal access, mitigation of instability with court rulings and data collection can be administered. Improving these areas of data collection can ultimately help in legal research and drawing conclusions to the patterns of high crime rates.

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Exploring the Relationship Between Hippocampal and Left Medial Temporal Lobe Atrophy and Cognitive Decline in Alzheimer's Disease By Jeongwon Park

Introduction

Alzheimer's disease (AD) is a progressive neurodegenerative disorder that causes cognitive decline and structural changes to the brain (Alzheimer's Association, 2023). AD is thought to be mostly a symmetric disease (both right and left lobes affected); although some work showing unilateral involvement initially (Wang 2022). One of the most well known trademarks of AD is the atrophy of the hippocampus and the left medial temporal lobe, which plays an important role in many cognitive tasks such as memory and verb information (National Institute 2017). This makes them the primary interest in understanding the effects related to AD, aiming to discover the connections between structural changes and cognitive decline. Similarly, as the disease progresses, the hippocampus, a crucial structure for memory, learning, and emotion, tends to degenerate, impacting memory function (Lakshmisha 2022).

Understanding the relationship between the left medial temporal lobe and hippocampus with cognitive measures in AD patients is important for furthering understanding of the disease and creating targeted treatments/interventions. Previous research has suggested that there is a correlation between the degree of degeneration in these regions with the severity of decline in cognitive decline observed in AD (Filho 2017). There have been studies on the extent of these associations, but replicating those results has been an ongoing investigation. The aim of this study is to investigate the relationship between hippocampal and left medial temporal lobe volumes with measures of cognition in Alzheimer's patients. I will be reaching my aim through an examination of pre-existing data from the Allen Brain Map on patient's MMSE scores and their brain volumes. The question I will be assessing in this paper is: To what extent are the volumes of the hippocampus and the medial temporal lobe related to measures of cognition in AD patients?

This paper aims to discover the nuanced connection between the structural changes of these two specific regions and the cognitive decline in AD patients. I hypothesize that a decrease in the volume of the hippocampus and the left medial lobe will be associated with a decrease in MMSE scores. The findings we can conclude from this research has the potential to enhance our understanding of the cognitive decline in AD patients, creating the way for more specific and personalized approaches to diagnosis, prognosis, and intervention for this detrimental disorder.

Methods

Participants

The data used in the study was derived from Seattle Alzheimer's Disease Brain Cell Atlas. There were 84 participants in the dataset used. The age of these participants ranged from 65 - 90+. Of the 84 participants, 42 had dementia and the remaining participants were cognitive normal

Materials

Two different types of datasets were used in this study: MRI Volumetrics and Donor

metadata. One of the datasets I used, MRI Volumetrics, contains the different volumes of various parts/areas of the brain. The second dataset, Donor Metadata, contains information on the different patients, such as their level of education, sex, age, and the cognitive information that I utilized, the MMSE scores.

Procedure

Before any data analysis, data processing took place to avoid any problems with R programming used later on. Any corresponding data of the missing data in one of the datasets were removed, so that the data aligned.

Then, with the processed and aligned data, I created two linear regression models, one with the data of the hippocampus volume and MMSE score, and the other with the data of the left medial temporal lobe and MMSE score. These linear regression models were created through R Studio programming.

Results

The Pearson's r value for the linear regression model when comparing the hippocampus volumes with the MMSE scores were close to 1, indicating a strong positive linear relationship. This meant that as the volumes increased, so did the MMSE scores, and vice versa. The coefficient was approximately 0.6978, which was the rate of change in MMSE scores for each beta-coefficient change in hippocampal volume. The r -squared value was 0.9733, meaning that 97.33% of the variance in MMSE scores could be explained by hippocampal volumes. On the other hand, the coefficient between left medial temporal lobe and the MMSE scores was 0.19883, meaning for every beta-coefficient increase in left medial temporal lobe volume, the predicted MMSE score increased by approximately 0.19883. The r -squared value was 0.1505, meaning that 15.05% of the variance in MMSE scores could be explained by the left medial temporal lobe volumes.

Discussion

The r value of the linear regression between the hippocampus and MMSE scores indicates that the independent variable did have a relationship with the dependent variable. This means that the changes of the hippocampus volume did have a great correlation with the MMSE scores of Alzheimer's Disease patients. However, correlation does not mean causation, which is a limitation of this study. On the other hand, the low r value of the linear regression model comparing the left medial temporal lobe volume and MMSE indicates that the changes of the independent variable did not have much effect on the dependent variable. This means that the changes of volumes that occur in the left medial lobe, does not correlate with the MMSE scores of Alzheimer's Disease patients. Therefore, the results do not support nor reject my hypothesis because my hypothesis only implies a positive correlation between both variables. However, there are some limitations to this study. The first limitation is data availability. There were many MMSE scores or the volumes of the different brain regions missing, so the number of data that I actually was able to use was limited. This leads to the second limitation which is the

sample size. Due to the fact that the sample size was small, it may not be representative of the broader population. Same goes for the sample bias. This data was collected from people with Alzheimer's in Seattle. There is a sample bias in this dataset and therefore, this study cannot be generalized to the bigger population.

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On Machine Humanity: Generative A.I. Art as a Means of Reflecting on Human Consciousness by Kailin Shi

The artist's understanding of their chosen medium(s) is the basis for their expression. An artistic medium's qualities— may it be its physical capabilities, inherent characteristics, or the medium's historical and contemporary role in society— can be viewed as both a constraint, or an opportunity to greatly amplify the artist's expression. Only through understanding these traits can the artist even select the most suitable medium for their endeavors. When photography was first invented, for instance, artists needed to understand how it was differentiated from other pictorial mediums in order to use the medium to their advantage. To what extent does photography state reality instead of interpreting it? How can tacit imperatives such as taste or consciousness still be imposed? How can artists retain control of the process when the act of taking a photo is so expedited in comparison to other mediums? How does the medium's ability to reflect reality like never before affect the way people view the work, or how artists interact with the medium? Through asking questions like these, advocates for photography were able to find the qualities of photography that justify its use to a skeptical 19th century audience. At the dawn of a new medium, understanding its inherent qualities is crucial as to understand how this medium will challenge and expand our definitions of art. This is especially the case with a medium as innovative and boundary-pushing as generative A.I. art.

Since the late 2010s, artificial intelligence art has undeniably attained socio-cultural relevance and continues to remain as a great area of contention in the art world. While the most well known form of A.I. art, text-to-image, have only garnered significant attention in the past decade with the rise of platforms such as Chat-GPT, Midjourney, Stable Diffusion, DALL-E 2 and Deep Dream Generator, in reality artists have been experimenting with A.I. since the 1970s. Now, many find it hard to justify the use of A.I. art, accusing the platform of fabricating other artist's intellectual property while not being able to provide any innovative or additive qualities to the artwork. Yet, although the increasingly realistic A.I. generated artworks are certainly an impressive indication of its technological potential, I argue that generative A.I. art's mirroring of the human consciousness through machine learning processes is its far more innovative and promising quality. Through examining the process of artmaking using generative A.I., from the artist's input to the algorithm's mechanisms, I highlight the ways in which generative A.I. art platforms mirror human cognition. I then propose several conceptual applications of these characteristics. The medium can be used to reflect upon themes related to the human consciousness such as perception and experience by examining how the algorithm processes its dataset and applies 'learned knowledge'. Through these philosophical applications, the abilities of A.I. art can be extended beyond beautiful renderings.

What is generative A.I. Art?

According to a “widely accepted”¹⁷ definition by Philip Galanter, generative art is defined

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by the use of an autonomous system for art making. Generative art can refer to any art practice where the artist cedes “partial or total subsequent control”¹⁸ to a system, such as a set of natural language rules or a computer program, to create a completed work of art. Contrary to what its ‘high tech’ name suggests, this subset of art is not defined by any particular technology but rather a reference to how the art is made. In fact, generative art does not need to rely on technology or computers at all.

In particular, using A.I. to create generative art creates another layer of autonomy. While other generative art systems may carry out ‘independent decisions’ through chance, A.I. platforms make decisions based on machine learning. All generative A.I. models rely on different processes, they are united by a few characteristics. First, these programs rely heavily upon its databases of images, which provide the algorithm with the basis of its learning. The database determines both the patterns the algorithm identifies and the product it can produce entirely; like us, the algorithm is limited by its perception of its ‘world’. Hence, through controlling the provided dataset, artists can control the process of image generation from start to finish. Admittedly, most commercial models, such as Midjourney and DALL-E 2, have already been trained on millions of images and text scraped from across the internet; hence, the artist’s ability to manipulate the algorithm’s learning processes and pool of knowledge is incredibly limited. However, A.I. artists working with their own algorithms have the freedom to curate datasets specific to their art practice.

Generative A.I. art comes in many forms and models. For example, Artist Harold Cohen’s ‘autonomous picture creator,’ an algorithm that instructs the computer to draw specific objects with the irregularity of freehand drawing, is considered the first of such applications of artificial intelligence to art, and certainly among the most simplistic. Inspired to “codify the act of drawing”¹⁹ when taking a post as visiting scholar at the Artificial Intelligence Laboratory at Stanford University, Cohen created AARON, a program designed to “work with random variables, making its own decisions on coloring and composition.”²⁰ Initially, the program created monochrome, abstract line drawings that had to be hand coloured by Cohen; by the 1980s, however, the program could not only make decisions on color choice but also create representational imagery of foliage and human figures.

Nowadays, however, technological advancements have allowed A.I. art to become far more complex than AARON’s line art and stick figures. The A.I. Art programs emerging in the mid-2010s have shown “remarkable potential”²¹ in generating realistic images from a dataset. In particular, Generative Adversarial Networks (or GANs for short) and Diffusion models have arisen as the most advanced approaches in the field.²²

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²² Cao, Hanqun, Cheng Tan, Zhangyang Gao, Yilun Xu, Guangyong Chen, Pheng-Ann Heng, and Stan Z. Li. “A Survey on Generative Diffusion Model.” arXiv.org, July 3, 2023. <https://arxiv.org/abs/2209.02646>.

GANs uses deep learning, also known as deep neural networks due to their construction of “multiple layers of processing elements analogous to the neurons of the nervous system,”²³ to discover patterns and regularities in input data and apply these observations to generate new examples based on the original dataset. GANs consist of two sub-models: a generator model used to generate new examples, and a discriminator that attempts to classify examples as real or fake (from the dataset or generated.) After training the models together, the generator should be able to fool the discriminator around half the time, signifying that the model is generating plausible examples.²⁴ Diffusion models use a process consisting of two steps: forward diffusion and parameterized reverse. The images of the dataset are first gradually processed to noise (or chaos) by perturbing the data in a stepwise fashion. Once the data reaches fully random noise, a reverse process is used to teach the model how to denoise the data and restore the original image. Such a process is repeated as the algorithm familiarizes itself with the visual patterns of its subject until it is capable of creating a novel image on its own. Other popular models include Convolutional neural networks (CNN), Neural style transfer (NST), and more.

In other words, the algorithm’s past experiences are entirely what shapes the way it perceives new data. Through this process, the system learns to recognize visual patterns such as color, texture, and form based on the provided dataset; this ‘knowledge’ is then applied to generate new images. The ability to learn and apply learning is arguably a distinct trait of cognition, and although currently A.I. is far from mimicking human thought processes, it is already one step towards becoming an accurate reflection of the human consciousness. Hence, A.I. art platforms can be used to reflect on human perception and human experience. Even as Cohen stated that AARON lacks “the most minimal intelligence ... the pre-existence of even a primitive set of cognitive skills ... built into [children’s] hardware,” Cohen’s referral to Aaron as an “entity” and “student” throughout the article and the name of the program itself²⁵ reveals that the author regards the program as an entity with its own autonomy and mechanical sort of cognition. As Cohen continued to experiment with the program, he began to view the program “as a collaborator rather than a talented assistant.”²⁶ Evidently, unlike past mediums which are completely subject to the artist’s will, A.I. art is capable of making its own interpretations and decisions, blurring its role from passive tool to proactive collaborator, robot to quasi-human.

²³ Hayes, Brian. “Computing Science: Delving into Deep Learning.” *American Scientist* 102, no. 3 (2014): 186–89. <http://www.jstor.org/stable/43707183>.

²⁴ Brownlee, Jason. “A Gentle Introduction to Generative Adversarial Networks (Gans).” *MachineLearningMastery.com*, July 19, 2019. <https://machinelearningmastery.com/what-are-generative-adversarial-networks-gans/>.

²⁵ Contrary to what its capitalization suggests, the program’s name is not an acronym but simply a seemingly arbitrary human name.

²⁶ Sundararajan, Louise. “Harold Cohen and Aaron: Collaborations in the Last Six Years (2010–2016) of a Creative Life.” MIT Press, August 9, 2021. <https://direct.mit.edu/leon/article/54/4/412/97258/Harold-Cohen-and-AARON-Collaborations-in-the-La-st>.

Perception

A.I. algorithms are the first ‘medium’ to be able to interact with and react to the artist’s ideas. Generative A.I. art platforms create new images by ‘perceiving’ images in their database and learning its patterns and forms. The algorithm processes the data with the knowledge it already has from previous ‘learning experiences’. By providing the algorithm with a curated database of images, the artist can learn ways in which A.I. perceive these images.

The algorithm’s reliance on past experience in interpreting new content parallels human perception. Humans too rely upon past experience in the way they interpret new experiences and information, letting their understanding of the patterns in their lives guide their assumptions. Though admittedly A.I. 's form of perception is more empirical and less influenced by other factors than human perception, experimenting with ways to alter the algorithm’s perception can too invoke the volatility of the way we experience our world.

London-based artist Memo Akten’s series of works “Learning to See” is an example of using A.I. perception to reflect on how humans make sense of the world. Akten manipulates random objects to create a series of images in close succession. These images are then interpreted by state-of-the-art Machine Learning algorithms based on its past knowledge of pattern and form. As a result, the artist’s hand holding an extension cord is transformed into multicolored flames, blossoming flowers, or a tranquil sea view.



Fig. 1 Memo Akten’s algorithm interprets an image of the artist’s hand as a flame.²⁷

“Of course [the algorithm] can only see what it already knows. Just like us.”²⁸ states the artist in introducing his series. Through observing how A.I. reconstructs new images based on its prior experiences, Akten’s series invokes questions on “self affirming cognitive biases, our

²⁷ “Memo Akten – Artist Profile (Photos, Videos, Exhibitions),” AIArtists.org, accessed August 26, 2023, <https://aiartists.org/memo-akten>.

²⁸ “Memo Akten – Artist Profile (Photos, Videos, Exhibitions),” AIArtists.org, accessed August 26, 2023, <https://aiartists.org/memo-akten>.

inability to see the world from other's point of view, and the resulting social polarization."²⁹ Just as the same extension cord can transform into flowers or flames based on how the algorithm was trained, human perception is unable to escape from the influence of past expectations. As even an objective algorithm is confined by its knowledge, this comes to show how nothing we perceive can be separated from ourselves.

Experience

The amalgamation of A.I.'s perception is the synthesis of its past knowledge into new images. Past mediums have mostly relied on the execution of a single artist's idea, with each image forming from the artist's mind alone. Yet the ability to empirically analyze visual similarities and combine images can be used to synthesize experience in an unprecedented way. Elaborating on how A.I. can be used to study consciousness and cognition, A.I. artist and programmer Gene Kogan states: "[A.I. art programs model] crowd-sourced datasets, which can be thought of as collections of human experience and perception." Indeed, through carefully curated datasets, A.I. can study the visual similarities and distill the images into key patterns and forms. The artist exercises meaningful control over the process by curating the dataset, hence manipulating the outcome and subject matter while still relinquishing some autonomy to the objective algorithm. The artist can select images that represent core concepts or values for the algorithm to interpret into its own forms. Through this, artists can study "those most mysterious questions that science has been impotent to tackle so far."³⁰ The ability to take inspiration and observe other artworks is certainly not a new one. If solely considering generative A.I. art model's ability to replicate, perhaps the medium does not bring much to the table. Yet A.I. Art platforms' mirroring of human cognition through its ability to learn and apply learning elevates its potential from mere artisan to something entirely unique in the art world. Though A.I. is certainly far from being able to capture the full complexity of the human mind, it is the first step in that direction. Artists who know to insert themselves into the artistic process through controlling datasets and finding innovative uses to this new technology can seize this unprecedented opportunity to reflect upon and explore human consciousness. Through art, we can recognize humanity in even the most artificial and mechanized of our creations.

²⁹ "Memo Akten – Artist Profile (Photos, Videos, Exhibitions)." AIArtists.org. Accessed August 26, 2023. <https://aiartists.org/memo-akten>.

³⁰ "Gene Kogan – Artist Profile (Photos, Videos, Exhibitions)." AIArtists.org. Accessed August 26, 2023. <https://aiartists.org/gene-kogan>.

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Addressing Disparities in Mental Health Services: The Case of the Bronx and the Need for More Mental Health Providers By Adrianna Lu

Abstract

Mental well-being is an issue often overlooked despite significantly impacting one's life. Although mental health issues have become more prevalent recently, specific communities are affected more than others due to their inadequate treatments. Despite being located in a wealthy city, the Bronx ranks last out of all the counties in New York regarding health outcomes. Health outcomes are ranked based on the life expectancy and life quality of the residents, and mental health plays a significant role in both. Most mental health patients in the Bronx are not receiving what is considered minimally adequate treatments. Many patients have also expressed distrust towards the healthcare system and health providers. Patients found it hard to build relationships with the health providers, due to a lack of communication. These results can be attributed to the lack of mental health providers in the Bronx. According to statistics, the Bronx has 425 residents per mental health provider, which is higher than the average in New York of 299, resulting in less efficient treatment and negative patient experiences. By increasing the number of mental health providers in the Bronx, patients should be able to connect with their providers more, building a trusting relationship and improving their treatment results and experience.

Introduction

As a fundamental element of one's overall well-being, mental health plays a crucial role in shaping people's lives and affects almost everyone at some point during their lifetime (Vigo et al., 2016). Recently, this recognition of the significance of mental health has increased drastically. Consequently, the development of mental health programs and services aimed at addressing these concerns as well as providing support to those affected by mental health issues has skyrocketed.

Amidst this increasing emphasis on mental health, comprehensive programs and services have emerged, targeting prevention, intervention, and support across diverse populations. These initiatives encompass a wide array of therapeutic interventions, counseling services, community outreach programs, and public awareness campaigns, with the collective objective of fostering psychological well-being and destigmatizing mental health issues. Yet, their capacity to fulfill their intended purposes and deliver optimum care hinges on the availability and efficacy of healthcare providers.

Through a comprehensive analysis of existing literature and evaluation of publicly available data, this research paper aims to provide an in-depth understanding of how the number of mental health providers impacts patient experiences of mental health programs in the Bronx. Additionally, this study will contribute to the ongoing discourse on enhancing mental health services and fortifying the resilience of individuals and communities facing mental health challenges.

Literature Review

Problem- Patient distrust and poor quality of mental health services in the Bronx

Mutual respect between healthcare providers and patients is a cornerstone of patient-centered care. Unfortunately, many patients in the Bronx have expressed feeling disrespected and marginalized by the healthcare system (Kaplan et al., 2006). The intersectionality of factors such as race, ethnicity, and socioeconomic class can significantly influence patients' interactions with staff members, exacerbating the sense of being treated inequitably (Kaplan et al., 2006). Additionally, effective communication between patients and healthcare providers is an indispensable element in fostering trust and ensuring successful treatment outcomes. However, patients in the Bronx have reported difficulties in effectively communicating with their physicians, leading to inadequate care (Kaplan et al., 2006). Cultivating a therapeutic environment where patients feel heard and respected is essential in establishing a foundation of trust that goes beyond transactional interactions.

A prevalent issue mental health service providers face is patient dissatisfaction, which can lead to treatment dropouts and compromised mental health outcomes (Andrade et al., 2014). A survey conducted in the Bronx revealed that African American patients, in particular, expressed fear and distrust of the healthcare system, harboring beliefs of receiving second-class care due to their race and ethnicity (Kaplan et al., 2006). These deeply ingrained perceptions highlight the pressing need for culturally competent and sensitive mental health services that address the unique challenges faced by diverse communities.

The provision of minimally adequate treatment is a fundamental principle that should underpin mental health services across the United States. However, the reality reveals a stark disparity, with the majority of mental health service patients not receiving the level of care they require (Wang et al., 2002). Out of 1,485 adolescents who had major depressive episodes, only 34 percent received adequate mental health care. Furthermore, of the adolescents who received adequate treatment, only a small proportion identified as minorities, showing that minorities, on average, receive lower quality health care than those who identify as white (Alegria et al., 2015). Given that minorities constitute the majority of the Bronx's population, it is crucial to thoroughly analyze the obstacles and difficulties encountered by patients seeking mental health services. This is especially true for those who live in the Bronx, where multiple factors influence the standard of care and patient-provider communication (Kaplan et al., 2006). The unmet need for minimally adequate mental health treatment is a critical issue faced by patients across the United States, particularly in the Bronx. The disparity in access to adequate care and high patient dissatisfaction underscore the urgency to address the challenges that impede effective mental health service delivery. To bridge these gaps, there must be a concerted effort to improve service accessibility, enhance patient-provider communication, and foster an environment of mutual respect and cultural sensitivity. By tackling these barriers, mental health services can be transformed to serve all patients better, ensuring that every individual receives the care they deserve to achieve improved mental well-being and overall quality of

life.

In addition to not providing minimally adequate treatment, the Bronx ranked last in rankings of different counties' health factors and outcomes in New York in 2022 (2022 New York Data, 2022). The two determinants of health outcomes used in this ranking are life expectancy and quality, both of which are directly related to mental well-being (County Health Rankings Model, n.d.). According to the World Health Organization, severe mental health issues can decrease one's life by 10-20 years (World Health Organization, 2022). Additionally, having poor mental health can contribute to having a lower quality of life as mental health issues can have negative impacts on one's emotional well-being, physical health, social relationships, occupational and daily functioning, academic performance, financial well-being, self-esteem, and an increased risk of substance abuse (Mayo Clinic, 2022). While the Bronx ranks last, other boroughs in New York City such as Manhattan and Queens ranked in the top 16 counties, showing the stark disparities in health outcomes within a developed city (2022 New York Health Outcomes Map, 2022). The evident disparities in access to minimally adequate mental health treatment and the concerning health outcomes in the Bronx emphasize the urgency for systemic change.

Cause- Lack of mental health providers in the Bronx

The average ratio of mental health providers to residents in New York is 1:299, whereas the ratio is 1:425 in the Bronx (2022 New York Data, 2022). This high number of residents per provider limits the residents' access to services and lowers the quality of the services provided. Cattaraugus County (ranked 61), Sullivan County (ranked 60), and Montgomery County (ranked 58) have mental health provider-to-resident ratios of 1:592, 1:493, and 1:1032, respectively (County Health Rankings & Roadmaps, 2022). On the other hand, Putnam County (ranked 1), Saratoga County (ranked 2), and New York County (ranked 7) have provider-to-resident ratios of 1:235, 1:290, and 1:98, respectively (2022 New York Data, 2022). The drastic difference in ratios shows a significant correlation between the proportion of providers to residents and the county's health outcomes.

One key issue highlighted by patients in the Bronx was the lack of communication between provider and patient. This lack of communication is usually driven by a lack of time on the provider's end (Kaplan et al., 2006). The lack of time can be attributed to the provider having to see many patients daily due to the low number of health providers in the area. Seeing many patients every day can also cause providers to burn out and experience high levels of stress, potentially causing unpleasant reactions to patients (Kumar, 2016). Research shows that long-lasting work shifts significantly decrease health providers' ability to perform to the best of their ability, making them viable to make medical mistakes (Lockley et al., 2007).

Various reasons can lead to the lack of mental health providers in the Bronx, including a lack of funding and access to quality education. Even though mental disorders affect most of the population to varying degrees during their life, the global burden of these disorders is gravely underestimated, leaving mental health institutions underfunded (Vigo et al., 2016). Additionally, many people do not realize that they have mental illnesses, adding to underestimating the

significance of maintaining people's mental health (Andrade et al., 2014). The stigma surrounding the topic of mental health also prevents many people from speaking out on their feelings, yet again contributing to how society undermines its importance and does not allocate enough resources to help those in need. This lack of funding and uneven resource distribution can lead to a lack of mental health providers in marginalized communities such as the Bronx. Another reason why the Bronx has a low number of mental health providers could be due to the residents' lack of access to the training necessary to become a healthcare professional. According to a survey done by the Center for an Urban Future, 20.5% of the people in the Bronx who are working age have a Bachelor's Degree (Shaviro et al., 2021). This percentage pales in comparison to the New York City average of 40.1% (Shaviro et al., 2021). Without first earning a Bachelor's Degree, one is unable to pursue a career in providing healthcare. In the Bronx, few people have access to higher education, making it harder to seek healthcare training (Bronx Community College, n.d.).

Solution- Increase the number of mental health providers in the Bronx

Seeing the correlation between the Bronx's lack of mental health providers and the county's poor health outcomes, a reasonable solution would be to increase the number of mental health providers. With more providers, each patient will get more one-on-one time to ask

questions and build a trusting relationship with the professionals, improving their experiences and increasing the effectiveness of the treatment. More providers also mean that each provider won't have to work as many hours and will be able to rest and be more productive when working. Increasing the number of providers will also increase the diversity among the providers, making patients feel more welcome and trusting of them. Furthermore, additional providers will increase access to treatments and create more personalized patient care.

There are two main ways to increase the number of mental health providers in the Bronx: by incorporating mental wellness into the curriculum of Bronx public schools and by expanding the funding for mental health institutions. Educating people about the importance of mental health when they are still in school may open up this field as a potential career path. Also, the more people are aware of the significance of mental health, the more changes for the better will happen in the future. Additionally, increasing the funds allocated towards mental health institutions will allow them to hire more professionals and further develop their treatment plans.

Conclusion

The Bronx, ranked last in health outcomes among New York counties, faces significant challenges in accessing quality mental health services due to the scarcity of mental health providers. This lack of providers also contributes to inadequate treatments, unsatisfactory patient experiences, and compromised health outcomes. Patient-provider communication and relationship-building emerged as crucial elements affected by the limited number of mental health providers (Kaplan et al., 2006). Patients also expressed distrust and dissatisfaction

towards the healthcare system, highlighting the urgent necessity for culturally competent and sensitive mental health services, particularly in a diverse community like the Bronx (Kaplan et al., 2006).

The number of mental health providers in the Bronx must be increased to address these critical issues. This can be achieved through targeted efforts such as incorporating mental wellness education into the curriculum of public schools, encouraging individuals to pursue careers in mental health, and allocating more funding to mental health institutions. By taking these steps, patients in the Bronx should be able to access more personalized and effective mental health treatments, fostering trusting relationships with providers, and ultimately improving their overall mental well-being and quality of life. Addressing the shortage of mental health providers in the Bronx is a crucial step towards achieving equitable and effective mental health care, ensuring that every community member has access to the support and treatment they need.

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Epimedium Suppresses Triple-Negative Human Breast Adenocarcinoma Cell Line Proliferation In Vitro by Buse Kurdoglu, Sude Kurdoglu, Sanem Naz Kafali, Cevriye Yildirim, Erkan Yurtcu

Abstract

We aimed to study whether Epimedium has an anti-proliferative effect on triple-negative cancer of breast cells. In this study, the cells employed were from a triple-negative human breast adenocarcinoma cell line, MDA-MB-231. The trypan blue test determined cell viability. Antiproliferative effects of Epimedium were determined using the assay of 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide. Epimedium extract was administered in 1 mg, 2.5 mg, and 5 mg doses. A reader of enzyme-linked immunosorbent assay assessed the chromogenic product's optical density at 540 nm. Tumor cell viability was calculated using the optical densities of Epimedium-treated cells. MDA-MB-231 cell growth was suppressed by Epimedium concentration-dependently. Cell viability at 1 mg dose of Epimedium was $108,93 \pm 0,11$; however, at 2.5 mg and 5 mg doses of Epimedium, it was $103,30 \pm 0,06$ and $77,74 \pm 0,15$, respectively. Epimedium reduced MDA-MB-231 cell proliferation concentration-dependently. Therefore, it might be regarded as a promising drug for the therapy of human triple-negative cancer of the breast.

Keywords: Epimedium, anti-neoplastic effect, triple-negative human breast adenocarcinoma cell line

Introduction

The breast carcinoma is the most commonly diagnosed cancer in the world (Arnold, et al.). It is also the most common carcinoma and an essential reason for cancer-related deaths among women (Arnold, et al.). As an aggressive, poor-prognoses type of it, triple-negative breast cancer (TNBC) possesses neither human epidermal growth factor receptor 2 (HER2) nor the receptors of estrogen (ER) and progesterone (PR) (Foulkes, et al.). TNBC is identified in nearly 15% of the cancers of the breast with characteristic features of shorter overall survival and higher relapse rates when compared to the other subtypes (Moran, and Sanft).

Due to the absence of necessary targets, TNBC resists endocrine hormonal treatments such as aromatase inhibitors, tamoxifen, and molecular HER2-targeted therapies such as trastuzumab (Moran, and Sanft). Standard chemotherapy cannot be given to relapsed or refractory TNBC patients due to poor treatment responses lasting a very short time and ending with rapid cancer relapses. Severe cell toxicity and side effects of the treatments, together with inadequate response to conventional chemotherapeutics, also make patients and scientists seek more effective natural medicines with fewer side effects as complementary or alternative therapeutic agents (Moran, and Sanft)

As anticancer agents, several natural medical extracts that induce tumor cell apoptosis and have effective cancer-fighting properties have been used successfully. Among these, camptothecin, vincristine and paclitaxel are very well-known ones (Chen, et al.). The research

focusing on Chinese herbal medicines to discover new natural anti-cancer molecules noticed Epimedium as a potential antineoplastic drug that inhibits tumor cell migration and growth and induces apoptosis. Epimedium has been extensively used as an herbal medicine for over two thousand years in China and includes about 260 components. Icariin (ICA), the main active compound derived from Epimedium, has been implicated with its anticancer effects, and its antitumor properties against various cancer types have been investigated (Chen, et al.)

Although Epimedium's antineoplastic impact on breast carcinoma has been studied, information exclusively on the cell lines of TNBC is scarce. Therefore, this investigation was conducted by high school students under the supervision of Prof. Dr. Erkan Yurtcu.

Materials and Methods

Triple-negative human breast adenocarcinoma cells, MDA-MB-231 (HTB-26), were obtained from the American Type Culture Collection (ATCC, Rockville, MD, USA). Dulbecco's Modified Eagle Medium (DMEM)-high glucose (Biochrom AG, Berlin, Germany) was used to maintain MDA-MB-231 cells. Heat-inactivated 10% serum of fetal bovine (HI FBS, Biochrom AG), L-glutamine (Biochrom AG), and penicillin-streptomycin antibiotic solution (Biological Industries, Kibbutz Beit Haemek, Israel) was used to supplement Media. In an incubator of the Heraeus model (Hanau, Germany), incubation conditions at 37 °C were provided within a humidified atmosphere with 5% CO₂.

The trypan blue test was used to evaluate cell viability. The study included cultures with 95% or more cell viability. A Thoma chamber was used to determine cell numbers.

Epimedium extract was purchased from a local manufacturer (Epimedium Ekstrakt 50 gr, Nurbal Şifa Merkezi). The extract was dissolved in dimethyl sulfoxide (DMSO). The DMSO concentration in cell cultures did not exceed 1%.

By using 3-(4,5-Dimethyl-2-thiazyl)-2,5-diphenyl-2H-tetrazolium bromide (MTT, Sigma, St Louis, Missouri, USA), the cytotoxic concentrations of Epimedium extract were determined. In 1 mg, 2.5 mg, and 5 mg concentrations, Epimedium extract was applied to cells. To each Epimedium containing well, a total of 1X10⁴ cells were then seeded. Following the plate incubation for 48 h at 37 °C, 20 µL from MTT in intensity of 5 mg/ml with a last volume of 0.59 mg/ml was included in each well, and the plates were further incubated at 37 °C for 4 hours. In the final incubation step, 100 µL of 10% sodium dodecyl sulfate (SDS) solution was included in each well. Following the plate incubation at 37 °C overnight, the absorbance at 540 nm was assessed with a reader of enzyme-linked immunosorbent assay (ELISA) (ELx800 Absorbance Microplate Reader, BioTek Instruments, Winooski, Vermont, USA).

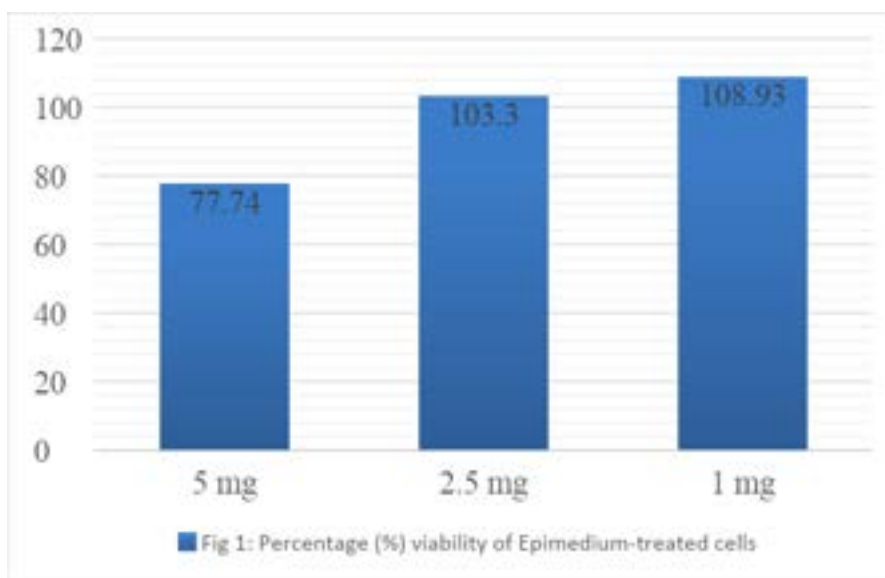
Using their optical densities (OD), the percentage viability of Epimedium-treated cells was calculated. Briefly, viable cell percentages were calculated by subtracting OD values of cell culture medium from treated and untreated cells.

Results

Epimedium independently suppressed MDA-MB-231 cell proliferation concentration (Table 1, Fig 1). The cell viability at a dose of 1 mg of Epimedium was 108,93%, but at 2.5 mg and 5 mg of Epimedium, the viability was 103,3% and 77,74%, respectively (Table 1). We discovered that the mean optic densities of medium and untreated cells were 0,3 and 0,99, respectively. The mean optic densities of the Epimedium-treated group at 1 mg, 2.5 mg, and 5 mg doses were 1,06, 1,02, and 0,84, respectively.

Table 1: Percentage viability of Epimedium-treated cells in various concentrations of Epimedium

Epimedium concentration (mg)	Percentage (%) viability (Mean \pm Std Dev)
5	77,74 \pm 0,15
2.5	103,30 \pm 0,06
1	108,93 \pm 0,11



Discussion

Currently, TNBC is treated with chemotherapy and radiotherapy (Manjunath, and Choudhary). Since it is highly invasive and adverse reactions to the therapeutics are significant, the treatment of TNBC is challenging. With their prominent effects against cancer and lesser side effects, natural products such as Epimedium are among the various promising drug candidates for its treatment (Gao, et al.).

The anti-cancer effect of Epimedium was implicated with ICA, which is a primary active compound of it (Chen, et al.). Our results from the cell viability assay showed that the inhibition of TNBC cell proliferation by Epimedium is dose-dependent. Epimedium had no cytotoxic effect

on MDA-MB-231 cells at the doses of 1 mg and 2.5 mg (103,3% and 108,9% viability, respectively), but its cytotoxicity on these cells was prominent at a dose of 5 mg (77,7% viability).

Similar to our findings, a recent study by Gao et al. revealed that ICA treatment strongly inhibited TNBC cell growth, and this anti-proliferative effect was concentration-dependent (Gao, et al.). Additionally, they found that ICA induced apoptosis concentration independently by accumulating excessive reactive oxygen species (ROS) and inhibited TNBC cell invasion by repressing the signaling pathway of JNK/c-Jun (Gao, et al.).

In another study by Song et al., similar to our study design, ICA's anti-proliferative role on MDA-MB-231 human TNBC cells was assessed via MTT assay (Song, et al.). They found that ICA selectively inhibited MDA-MB-231 cell viability and proliferation concentration time-dependently. In addition, by regulating the immunosuppressive microenvironment of tumors, ICA exhibited a significant anti-pulmonary metastasis effect. They concluded that ICA effectively inhibits breast cancer cell migration and triggers apoptosis by using the signaling pathway of SIRT6/ NF- κ B (Song, et al.).

Recently, the development of TNBC has been implicated with ER- α 36, an isoform of ER-alpha (Zhang, et al.). ER- α 36 promotes the malignant TNBC cell growth, and thus, it has been suggested as a promising target for novel drug development for TNBC (Zhang, et al.). Wang et al. evaluated the role of icaritin (ICT), which is the main metabolized form of ICA after ingestion (Bi, et al.) on TNBC cell growth and its underlying mechanisms (Wang, et al.). Their study showed that ICT decreased both the expressions of EGFR and ER- α 36 and promoted apoptosis in MDA-MB-231 cells, which were also the same TNBC cells used in our research (Wang, et al.). They also found that ICT inhibited estrogen-induced cyclin D1 and ER- α 36-mediated MAPK/ERK pathways (Wang, et al.). These findings make us think that estradiol-stimulated cell growth in TNBC may also be inhibited by disrupted ER- α 36/EGFR positive regulatory loop by ICT, which has a selective estrogen receptor modulator (SERM)-like activity (Wang, et al.).

In conclusion, our results revealed that Epimedium may show a dose-dependent cytotoxic effect on TNBC cells, indicating that it is a promising drug candidate in the therapy of human TNBC.

This study was carried out by high school students who aspired to be doctors in the future, accompanied by a senior researcher.

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Racism In Healthcare By Nyrah Siddiqui

Abstract:

Racism and healthcare are both pressing issues in the United States, so one would imagine their confluence is rather complex. From black neighborhoods that were redlined to exclude hospitals to physicians who introduced scientifically false beliefs about African bodies, African-Americans have been intentionally disadvantaged in the healthcare system since 1866. Many issues regarding the African-American community are talked about, yet healthcare has rarely been one of them. With modern society being so progressive, it's hard to believe that racist healthcare exists, but it does. The average person may not know that racist healthcare exists, but those who have experienced it do. This is precisely why it is imperative that the public gains knowledge about African-American experiences in the healthcare system. This paper will analyze the history of racial malpractice, examine various African American experiences in the modern healthcare system, and explore solutions and improvements to racist healthcare. With a broader and deeper understanding of racism and healthcare, this paper aims to educate and encourage the public to push for change. People think that since our world is much more progressive today, racism is practically solved, but it's not. By identifying and analyzing the historical and modern-day abuse of African Americans in the healthcare system, I will help the reader understand the background and connections that history has created and therefore encourage them to be a proponent of cultural reform.

Keywords: Society, Racism, Medicine, African American Experience

Introduction

During the early 1800s, both dissection and experimentation were used as a mechanism to exploit African-American bodies. Yet it still happens today, we can see this through the lens of African American women who experience racism pre- and post-partum. In this paper, the reader will learn about how past history has influenced current healthcare and explore possible solutions to it.

Section I

History

Racist healthcare in America has its roots in the 1840s, a time of mass slavery and careless experimentation. The initiation of centuries of racist healthcare began with the practice of nonconsensual dissection; in other words, physicians prioritizing their own interests over what was moral. Slave owners desired two things: money and power, and both were best achieved through exploitation, in this case, the exploitation of African American bodies. Physicians also valued money and power, which made their interests similar to those of slave owners: "Most physicians shared the economic and political interests of slave owners and conspired with planters, their real clients, to subjugate slaves by invading their bodies" - pt.1 p. 31. Washington,

Harriet A. (2006). *Medical Apartheid*. Doubleday. Through lending their slaves to physicians for “medical research”, slave owners earned the right to vaunt that part of the research “belonged” to them. In return, physicians earned the right to vaunt that they discovered something “new” (and biologically false) about African American bodies. However, dissection was only the inception and validation for future experimentation on African Americans

Physicians soon realized that dissections weren’t enough to produce valid results for research, they needed experiments. John Brown, a slave, had a master (Mr. Stevens) who fell very ill and went to see a doctor: Dr. Thomas Hamilton. Dr. Hamilton cured Mr. Stevens within days, and in return, Mr. Stevens promised to grant any favor that Dr. Hamilton had to ask of him. Dr. Hamilton’s request was for Mr. Stevens to “lend” him Brown, without inquiry, Brown soon was in the temporary custody of Dr. Hamilton. Dr. Hamilton used Brown for experimentation purposes, the first experiment being one where Dr. Hamilton aimed to find a cure for sunstroke. In this experiment, Brown was put in a pit that contained embers that caused temperatures to exceed 100 degrees Fahrenheit, only Brown’s head was exposed, and just 30 minutes into the experiment, Brown fainted. After developing a cure for sunstroke, Dr. Hamilton continued to use Brown for another experiment. In this experiment, Dr. Hamilton wanted to ascertain how “deep” black skin went, he did this by blistering Brown’s hands, legs, and feet at two-week intervals, Brown bore the scars for years. The other experiments that Dr. Hamilton performed on Brown were too inhumane for Brown to even recite. Brown eventually fled from Georgia to England. - *Medical Apartheid*, pt.1 p.52. Washington, Harriet A. (2006). *Medical Apartheid*. Doubleday. Stories like these are prime examples of physicians’ lack of empathy towards others, they never cared to put themselves in anyone else’s shoes. This lack of empathy is what caused physicians to become evil actors in the antebellum South. At this time in history, physicians were indifferent to how inhumane these experiments were, they only cared about their own personal profit and justified their actions through racial means. Both experimentation and dissection became the norm.

Dissection and experimentation carried on throughout the 1800s and even into the late 1900s. They became so ingrained into American healthcare culture that they were simply swept under the rug. Even as the world became more progressive, many were still blind to the injustices that were being carried out right under their feet. In 1977, Sixty-eight-year-old Casper Yeagin went missing, his family filed a report but it was ignored. However, the police did agree to put Yeagin’s description profile against that of the recently deceased unidentified patients at Howard University Hospital, and they found a match. Yeagin’s body was then found on a slab in the anatomy lab of Howard University’s Medical School, on the verge of being dissected. After further investigation, it was found that Yeagin’s remains were sent to the Medical Examiner’s office through lottery, and then his body was given to a medical school, Howard. Yet, his family was given no information regarding Yeagin’s death in the first place. - *Medical Apartheid*, p.1 pg. 115. Washington, Harriet A. (2006). *Medical Apartheid*. Doubleday. The significance of this anecdote doesn’t lie in the immorality of the dissection, but rather in the injustice that came as a result of it. Yeagin’s family never received any information about his death or the events that

occurred after it, they weren't able to give him a proper funeral, instead, medical students earned the right to cut into his body as if it were a prop. The Emancipation Proclamation could be passed and slaves could be freed, but the racism enshrined in the roots of healthcare stayed. Experimentation didn't stop at adults, African-American children were mercilessly taken from their homes and forced to participate in medical experiments. In an experiment spanning from 1992 to 1997, representatives from Columbia University knocked on Charisse Johnson's door asking to "borrow" her son. They said they needed him at the hospital overnight to conduct simple interviews and inject a harmless medication. Their "goal" was to offer a safe free test for Isaac to discover if he had any medical problems. Although she hesitated, Johnson eventually agreed. Isaac soon became part of an experiment in which 126 African-American boys were administered a stimulant to cause their serotonin levels to increase. An increase in serotonin leads to an abundance of prolactin in the blood. But if the prolactin levels increased "too" dramatically in response, researchers would deem that the boy had a biological brain dysfunction that may signal a tendency towards aggression. - Medical Apartheid, pt.2 p. 271. Washington, Harriet A. (2006). Medical Apartheid. Doubleday. This experiment was fundamentally flawed because instead of testing the prolactin levels in the children's blood with their natural serotonin, a stimulant had to be added so their prolactin levels could increase and they could easily be labeled as "aggressive". Sometimes, experiments weren't even done correctly, they would be manipulated to create false narratives about African Americans.

Experimentation and dissection were only the start of something much bigger, racist healthcare. Racist healthcare was created two centuries ago, yet, it's still here with us today. Maybe not in the same forms of experimentation and dissection, but in a more clinical setting with pre- and post-partum healthcare.

Section II

Modern Racism

Progressive thought doesn't mean progressive change, racism is still prevalent in the modern world and we can see this through the lens of the mistreatment of African American women in a clinical setting. Whether it be infringements on bodily autonomy or dismissing symptoms of the patients, we will take a deep dive into the apathetic quality of treatment that some physicians provide to African-American patients. One may think that if you as a patient are being mistreated, you should just "stand up for yourself", but for African American women, it's not that easy. Through three anecdotes, we will analyze the severity of the stigmas around African American women and how it affects their quality of healthcare.

The following anecdote represents an example of physicians being adamant in regard to their patients' decisions. For context, the cervix must be dilated 10 centimeters to give birth to a child, so when you're dilated at 7 centimeters, it's safe to say you're pretty close to being fully dilated.

Miller, Claire Cain, and Sarah Kliff. “Unwanted Epidurals, Untreated Pain: Black Women Tell Their Birth Stories.” *The New York Times*, 6 May 2023, www.nytimes.com/2023/05/06/upshot/black-births-maternal-mortality.html.

A 32-year-old African American woman, Lia Gardley wanted to give birth naturally, she knew that if she was 7 cm dilated, then she would be able to make it through the entire birth naturally. While in labor, she repeatedly asked the doctors how many centimeters dilated she was, yet they kept denying her request. The doctors then just suggested that she was in so much pain that she should just take the epidural, unsure of how much labor she had left, she hesitantly agreed to the epidural. Only to find out later that she was past 7 cm dilated and she would’ve quickly gone through the entire process naturally. A woman should have the full right to give birth as she chooses, yet, physicians sometimes make this impossible. Natural births are births that are completed without the use of an epidural (a local anesthetic which numbs the lower spinal nerves to block pain during labor). Sometimes natural births are preferred by women because it allows them to be fully present and savor the moment in which they bring their child into the world. In this case, specifically, it’s important to understand that women deserve the right to information about their bodies during labor, which in this case, was denied too. Physicians refusing to disclose such information is just a way for them to assert their nobility and power over a patient of color. Lia Gardley was forced to give birth to her child in a way she didn’t want to, just because her physician implicitly forced her to. Gardley had to be only 3 centimeters more dilated before she could complete her desired natural birth, but her physicians robbed her of this desire, simply because they didn’t “feel like ” saying a number out loud. This anecdote proves that racism doesn’t need to always take form in an explicit phrase or action, racism can also be expressed through indifference. Indifference is becoming an increasingly popular way to express internal bias. It’s the 21st century, people are rarely going to go out of their way and say racist things. This does not mean racism doesn’t exist anymore, it’s simply the fact that racists now have a fear of being “canceled” and chastised by the public. Indifference is dangerous, sometimes even more so than explicitness. Pay attention to indifference, it’s subtle but meaningful. The relationship between a physician and a patient should be that of mutual respect, but when one tries to use their nobility to assert their dominance falsely, this becomes unattainable.

When African American women want to combat this “indifference”, they must stand up for themselves; but with the labels and stereotypes society has created, this becomes nearly impossible. The next anecdote is included to show how easily physicians tend to dismiss the pain that African American women experience during labor, and why these women have little power to change that.

Miller, Claire Cain, and Sarah Kliff. “Unwanted Epidurals, Untreated Pain: Black Women Tell Their Birth Stories.” *The New York Times*, 6 May 2023, www.nytimes.com/2023/05/06/upshot/black-births-maternal-mortality.html.

An African American woman, Sade Meeks had to have a difficult emergency c-section in which she kept fading in and out of consciousness. Somehow, she was discharged from the

hospital only 3 days later even though she could barely stand. The physicians kept telling her “You’re a woman, you’re strong, other women have been through worse”. She was worried that if she started being assertive or making demands, she would be labeled as the “angry black woman”, so she went home. A day later she was still in pain, so she went to the ER of another hospital and was diagnosed with a serious infection, she spent weeks in the hospital away from her newborn daughter. She even tried sending breastmilk to her but the logistics proved futile. Thinking that African Americans have a higher pain tolerance is an age-old anachronism that was developed by racist physicians. Yet, [MNT’20](#) found that 73% of Caucasian medical students had at least one biologically false belief about African American patients. As discussed in the first section, racist physicians consistently put African American slaves through painful experiments so they can create these false beliefs about their bodies, and it worked. Physicians tend to bring these false beliefs into their clinical environment, which in turn, creates catastrophic consequences for the patient, such as the severe infection Sade Meeks developed post-partum. That’s not even the worst part, the worst part is that Sade didn’t have a voice, and she couldn’t stand up for herself. She says: “It was traumatic, and I felt like I’d failed not only myself but my child, I wish I’d been more assertive with my concerns, but they kept brushing them off.”. It’s very easy to think that Sade’s entire situation could’ve been solved if she was just more assertive, but it’s not that easy for African-American women. Society has created a stigma around African American women that if they stand up for themselves, that automatically makes them “angry” or “crazy”. So I’m sure now one can understand that in this situation, Sade was simply helpless. If we want healthcare facilities to be a safe space for African Americans, we must first eradicate all of the false narratives that were created years ago. This final anecdote shows that even when an African-American woman does stand up for herself and combat this indifference, her efforts can prove to be futile.

holliday, grace. “I Felt I Was Being Assessed on My Skin Colour”:

Black Women around the World Share Their Birth Stories.” *The Guardian*, 13 Aug. 2022, www.theguardian.com/lifeandstyle/2022/aug/13/black-women-around-world-share-birth-stories-Pregnancy-racism.

During her first birth, Louise Whittmore tore badly and needed stitches. The stitches were done poorly and Louise didn’t heal, When she returned to the doctor, the doctor refused to admit that a mistake had been made and didn’t redo the sutures. Due to this, Louise tore in the same place during the birth of the rest of her children. Soon, she may need surgery.

When you have skin and tissue tears in the same place, twice, it’s pretty obvious that you weren’t stitched properly in the first place. These stitches are difficult, but refusing to do them again is not an excuse. When you consistently tear in the same place, the injury will only worsen, which is why Louise may now need surgery. Louise now has to suffer the consequences of consistent infections and tearing every day, just because her physician refused to redo some stitches. The impact of this anecdote doesn’t lie in the adamantness of her physician, but rather in her physician's refusal to listen to her. Every patient has the right to discuss their condition with

their doctor, yet, for African-American women, this is a luxury. If they stand up for themselves, they're "the angry black woman", if they don't, they suffer the physical consequences.

These three anecdotes express different ways in which the behavior of physicians can affect the quality of care that African-American women receive. False narratives, apathetic care, and stigmas. These are the three main factors that affect patient care in clinical settings. It's simple: African American women have three chronological obstacles in healthcare: mistreatment by physicians, society revoking their rights to advocate, and futile efforts to create change. No justice has ever been brought to any of these women. To fix these issues, there needs to be cultural reform.

Section III

It's easy to educate people, but difficult to create change. That's why now knowing what you learned from the first two sections, I will teach you how you can translate that knowledge into change. Physicians have an ethical obligation to treat all patients equally, but they're failing. Since racism has been structurally instilled in our healthcare system, its solution is cultural reform. By applying Forbes' method of cultural reform to the healthcare world, physicians can create substantial change. First, they'll get rid of the habit, build a new one, and finally, instill a system of ethical leadership.

Rock, David. "The Fastest Way to Change a Culture." Forbes, 24 May 2019, www.forbes.com/sites/davidrock/2019/05/24/fastest-way-to-change-culture/?sh=625569313d50. Accessed June 23.

Racism is simply a form of a lack of respect; in this case, a lack of respect for people of different races.



The first step physicians must take toward cultural reform is getting rid of the racist habit. Physicians must understand that there is a new priority: minimizing racism in healthcare is more important than profit and personal bias. Once physicians understand this key principle, they can start to make a conscious effort to create change; and this is done through a system. A system in

this context is a method in which a physician achieves their priority. The best system for physicians to use is a system of ethical leadership.

Mintz, Steven. "The Role of Ethical Leadership in Organizational Culture." *Workplace Ethics Advice*, 25 Aug. 2021, www.workplaceethicsadvice.com/2021/08/the-role-of-ethical-leadership-in-organizational-culture.html.

In this system, physicians are expected to be respectful by practicing three actions: serving others, manifesting honesty, and showing justice; then eventually building a community around these ideals. This would be one of the most effective systems because physicians have the most ethical responsibility since they are dealing with people's lives. This system starts with respecting others, a physician should be able to recognize that their patient is also a respectable human and deserves to be treated with the same respect; if not, unwanted epidurals will be administered. In a healthcare context, respect has 3 components: serving others, manifesting honesty, and showing justice. Starting simple with serving others, this simply refers to the obligations physicians have to show up to work every day and do their work. But, how should this work be done? This work should be done by using the second component: manifesting honesty. Manifesting honesty refers to the act of staying true to your job, physicians don't sign multitudes of contracts to violate them. Physicians must respect the ethics of their jobs and treat patients equally, without race being a factor. The third component is showing justice. Notice how in each of the three anecdotes, the issue at hand was not solved or even dealt with. Since these cases of malpractice are being swept under the rug, it is impossible to bring attention to them. To create substantial change, we must accept the problem and work towards solving it. That's why it is imperative for there to be a just environment: an environment where physicians are held accountable for their wrongdoings. Finally, this system of respect is completed by building a community. This community consists of both doctors and patients who develop a trustworthy and ethical bond through fulfilling the components of respect, which again include, showing up, performing your job ethically, and bringing justice to those affected by racial malpractice. The second step physicians must take toward cultural reform is building a new habit. The habit is built through the ethical leadership system. By following the 3 components of respect, physicians have the potential to create change, but the change will only occur when it becomes a habit. This means that physicians consistently have to follow the ethical leadership system. To do this, they must create motivation for themselves. Motivation can be created by following the ethical obligation they have as a physician to treat all patients equally. They shouldn't be the physicians who refuse to announce dilations, they shouldn't be the physicians who are condescending to their patients, and they shouldn't be the physicians who refuse to redo incorrect stitches. Once the system becomes a habit, the change is substantial. To continue the progression, the system must be instilled. To instill the habit is to instill the ethical leadership system. In this case, this just means that physicians should consistently follow those 3 components of respect always, and eventually, it'll become second nature, and therefore produce a new "normal". To instill a system, it's also important to advocate, inspire, and imagine a future. A future where physicians

and patients are able to trust one another. To imagine this future, physicians must promote what could be, whether it be in their clinic or at the dinner table. For too long, African American patients have been consistently disadvantaged in the healthcare system, it is 2023 yet we are still not seeing substantial change. That is why physicians must follow the 3 components of respect and spread it throughout the healthcare community. This is imperative to the success of cultural reform.

Physicians must understand their priority is to treat all patients equally, and they can achieve this through the ethical change system. Once they have set their system and produced substantial change, they can begin to inspire other physicians to do the same, and slowly, they will create cultural reform.

Starting in the 1800s, African Americans had to deal with unwanted experiments and gruesome dissections. Yes, it's the 21st century and America has taken big strides toward cultural reform in regards to LGBTQ+ rights, women's rights, and even racism. Yet, racism in healthcare continues to be the anachronism that nobody wants to talk about. Racism against African Americans spans a much wider wing, and in that wing, is racist healthcare. Sure, no one unethically experiments on African Americans anymore, and why would they? For a physician, there's too much at stake, i.e. the fear of being "canceled". So if a physician does have a personal bias, they'll have to show it in an implicit manner, such as indifference, i.e. refusing to tell an African American patient how many centimeters dilated she is. When patients see this racism taking an implicit new form, they want to stand up for themselves, but they can't; considering the image that society has created of them being "angry black women", this seems remotely impossible. But let's say African American patients do try to stand up for themselves, then, physicians dismiss them with indifference yet again and think that their way is the only way. The personal racial biases that physicians have is rooted in a lack of respect: and lack of respect in this context means a lack of serving, honesty, and justice. You show up to the clinic every day, but you are not honest in completing your job ethically according to all your contracts. You show up to the clinic every day, but you don't bring your patients who have been mistreated to justice. That is the issue with our healthcare system. To fix this, we must accept that it has been historically instilled in our system, then we must start to read into the ethics of the medical profession and start treating everyone equally. Then we can finally say that we have eradicated racism in the modern era.

Time Series Forecasting and Prediction of COVID-19: A Comparative Study of Classical Machine Learning Baselines and Recurrent Neural Networks By Pari Bhandari

Abstract

Classification and prediction of different diseases using machine learning models has been a subject of research worldwide. One such was the Coronavirus (COVID-19), an infectious disease caused by the SARS-CoV-2 virus, that led to a global pandemic taking a toll on the health as well as socioeconomic conditions of people worldwide. This phenomenon highlighted the need to accurately detect the presence of COVID-19 in individuals based on their symptoms. This study aims to identify the most suitable machine learning model that helps predict the Coronavirus by analyzing patterns in the data collected from medical sources such as patient records and lab test results. They are trained on a large dataset to identify risk factors and early warning signs of diseases. As a result, they can also be used as a tool to determine the most likely diagnosis based on the symptoms of a patient. In addition to classical machine learning models, this research paper also implements the use of recurrent neural networks in the prediction of Covid-19 based on various attributes. This paper draws a comparison between the models on the basis of their performance and summarizes their results to draw a significant conclusion.

Keywords

Machine Learning, Recurrent Neural Network, Covid-19, Gated Recurrent Units, Classification Models, Time Forecasting

Introduction

The coronavirus disease 2019 (COVID-19) pandemic is a global outbreak of coronavirus – an infectious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Cases of novel coronavirus (nCoV) were first detected in China in December 2019, with the virus spreading rapidly to other countries across the world. This led WHO to declare a Public Health Emergency of International Concern (PHEIC) on 30 January 2020 and to characterize the outbreak as a pandemic on 11 March 2020 (1).

Amidst the pandemic, one of the most important questions raised by clinicians and patients was understanding which measures should be used to correctly diagnose or assess the disease based on a variety of symptoms (2). Preventing an illness is easier if it is identified at an earlier stage, which is why we need a reliable system to aid us in detection of diseases before they become incurable (3). Therefore, employing technology in the healthcare industry is a necessity that we can recognize.

The limited resources or data sets have always posed a problem for the adequate training of models. For example, training an AI-based detector requires a large database encompassing the full spectrum of possible anatomies, pathologies, and input data types. Data like this is hard to obtain, because health data is highly sensitive and its usage is tightly regulated (4). However,

with time, a lot of research data and patient records of hospitals have become available. There are many open sources for accessing the patient records and conducting research.

All this data can be used for very detailed personal profiling, which may be of great value for behavioral understanding and targeting but also has potential for predicting healthcare trends. In this era of automation, artificial intelligence and data science have an important role in this industry. These technologies are so well-connected that medical professionals can easily manage their roles and patient care (5). Scientists are working on machine learning (ML) to develop smart solutions to classify or predict the results as well as diagnose and treat disease. To achieve this, we need to integrate comprehensive patient data with broader contextual factors to distinguish between individuals who are healthy and those who are sick. This approach will help uncover biomarkers that can predict health shifts (6).

Machine learning is a branch of artificial intelligence which enables systems to learn from past data, identify patterns, and make decisions with minimal human intervention. Deep learning, a subset of machine learning, is particularly useful for medical imaging, where it employs multiple processing layers to learn data representations and extract features at various levels of abstraction (7). One example of a deep learning technique is the Recurrent Neural Network (RNN) (8). In machine learning, there are various models that can be used for detection and classification of diseases. A machine learning model is the output of the training process and is defined as the mathematical representation of the real-world process. The machine learning algorithms find the patterns in the training dataset, which is used to approximate the target function and is responsible for mapping the inputs to the outputs from the available dataset (9).

There are two types of models used in this research- the classical machine learning models and deep neural networks. However, depending on the dataset, the performance of the models is slightly different. This research explores and compares the validity of the classical machine learning models to more advanced ones in deep learning, for the detection and classification of COVID-19 using a large dataset.

Methodology

In this research paper, 80% of the data is used for training of the ML models while the remaining 20% is used in testing. The recurrent neural network models as well as the classical machine learning models are implemented on the dataset and their results are compared among themselves. The models were provided with a training set of data containing the various symptoms along with the corresponding test indication (disease present or absent) and test sets of data for which they had to generate the results. The disease detection and classification models were challenged to generalize by operating on unseen data that was not used for training.

Datasets

The Covid-19 dataset obtained from GitHub contains about 2.75 million instances and eight attributes of various symptoms. It comprises about 80% training data and 20% test data. The patients' (instances) test results were spread over one year. Various libraries and packages

were imported such as numpy, random, pandas.matplotlib, keras, and sklearn for the classical machine learning models that are Logistic Regression, AdaBoost, and Random Forest from GitHub (10).

On importing necessary modules, we then perform some data preprocessing steps. The initial step involved sorting the dataset by test dates in a chronological order. Subsequently, an array containing only the unique test date values was created. Using a for loop, we iterated over each unique test date to count the number of positive test results. For each date, the dataset was filtered to include only the entries corresponding to that specific date, and the counts of positive test results were recorded.

Then, we appended a column to the dataset titled `total_positive_results`, which contained the cumulative count of all positive results for each unique test date. This column was populated by repeating the count of positive results for every entry corresponding to the same test date. Following this, we created a separate dataset that included only the positive test results. This subset was extracted from the original dataset by filtering out all entries where the test result was not positive, thereby isolating the cases of interest for further analysis.

Next, we categorized the dataset containing positive test results into bins based on the cumulative count of positive results. Using a for loop, we iterated through each entry and examined the value in the `total_positive_results` column and assigned it to a specific bin based on predefined ranges. The bins are defined such that any value between 0 and 100 (inclusive) gets mapped to bin 1, values between 101 and 200 (inclusive) get mapped to bin 2, and so on. There are no values above 6000 and hence are not included in any bin. The bin ranges are provided below:

Total positive results (inclusive)	Value of Bins
0-100	1
101-200	2
201-300	3
301-400	4
401-500	5
501-600	6
601-700	7
701-800	8
801-900	9
901-1000	10
1001-2000	11
2001-3000	12

3001-4000	13
4001-5000	14
5001-6000	15
6000+	None

Table 1: Results mapped into various bins

Following the binning, we sorted the positive test results data and created an array with only the unique dates. Subsequently, we calculated the average number of positive test results per day by dividing the total count of positive results by the number of unique test dates available. Next, we established a parameter to indicate the number of days into the future for which we intend to predict COVID-19 test results. Initially, the value is set to 1. On multiplying this with the average number of positive results per day, we obtained the number of records in advance for which we intend to predict the test results.

Using the OrdinalEncoder class from scikit-learn, we encode string variables (like gender and whether they are 60+) in the data to binary integers (11). Later, we split the data into training input set and training output set where training input set corresponds to all the parameters or symptoms of different people in columns one to six and then from eight to ten, whereas the training output set refers to the final result (positive, negative or other) that is present in column seven. This marks the end of data processing. Then, we train and test various models on these sets and calculate their efficiencies through evaluation metrics.

Models

Deep learning models (12) use multiple layers of interconnected neurons to learn hierarchical representations of the input data. By increasing the number of layers in a deep learning model, the model can learn more complex and abstract representations of the data, which can lead to better accuracy and lower loss (13).

First, we initialize the hyperparameters (14), namely the timesteps, number of classes (bins) and number of features (inputs). The timesteps are set to 100 telling the model to look back at the last 100 time steps (e.g., days, hours, etc.) to make its prediction. The number of classes is 15 since we've categorized the output variable into 15 bins. The number of input features to be used by the model for its prediction is set to 7.

Next, we define two functions: the training input function and the training output function. The training input function is assigned with relevant columns consisting of the input variables (symptoms, age, test indication and date) extracted from the dataset with only positive results. Then, the function is trimmed from the end to exclude the number of records in advance that need to be predicted. This is done because every training example has an input feature that should correspond to the target variable (future value we want to predict). It ensures that the input features don't include data points for which we don't have corresponding future values in the target output variable. Similarly, the training output function, taken from the number of

positive result bin's column, is offsetted by the same amount (the value of number of records in advance) in the start to ensure each output represents the future predicted value based on the past values (training input function). Then, the target variable is converted to a numpy array and reshaped as -1 to +1 so that it has the correct shape for the encoder as a 2D numpy array with one column. Lastly, we use OneHotEncoder (15) to convert the training input function from categorical bins to encoded binary format.

Then, we calculated the number of valid training examples that could be generated from our dataset and stored it in a variable called data size. Given the total number of records in the positive results dataset, we subtracted the length of the input sequences (timesteps) and the number of future steps to predict (number_records_advance). We then initialized two arrays to hold the input and output variables for the training process. The input variables array had the dimensions: the new data size, the timesteps and the number of input features. It was created to store the input sequences. The output variable array had the dimensions: the new data size, the timesteps and the number of bins. It was created to store the corresponding target sequences. To fill in these arrays, we iterated over the dataset with the number of iterations equal to the new data size. For each starting index, we identified the corresponding future position for the target value. We extracted the input sequence and the future target value (output value), storing them in the input variable and output variable arrays respectively. This process ensured that our training data was correctly aligned.

To split the dataset into training and testing subsets, we use the input variable array, the output variable array and the test size as parameters. The test size is set to 0.2, which signifies the proportion of dataset to be used for testing. Here, 80% of the data is used for training and the remaining 20% is used to testing. Once the training and testing subsets of the inputs and outputs are generated, we move on to training the machine learning models and comparing them using an evaluation matrix (16). Recurrent baseline models are used in this paper prior to implementing the unidirectional and bidirectional gated recurrent units. The three baseline models used here are as follows:

- Logistic regression (LR): It uses a multinomial classification approach with a LBFGS solver where the usual sigmoid logistic function is replaced by a softmax function and the class probability which sums up to one is computed as a function of the inputs (17).
- Adaboost (AB): The Adaboost algorithm uses an ensemble of weak learners combined and weighted to arrive at a model's prediction whilst iteratively improving on instances misclassified by previous classifiers (18, 19). Used with a hundred estimators.
- Random Forest (RF): The Random Forest algorithm is an ensemble of individual decision trees where each tree predicts the class when used in a classification framework, and the class with the most votes becomes the model's prediction (20). Used with a maximum depth of three.

For each one of them, two functions that are for training and testing were defined. For the training function, the classifier is trained on the training input set whereas the testing function

tests the trained classifier on the test output set. It returns the accuracy of the classifier on the test data and the predicted labels. This is done for all the models, after which the accuracy, precision, fscore and recall of each one is computed and compared. Previously, a parameter was created to indicate the number of days into the future for which we intend to predict COVID-19 test results. These three baselines models were implemented for both one day and two days in advance forecast tasks.

For implementing the deep learning models, two functions that train and save recurrent neural networks (RNNs) with Unidirectional Gated Recurrent Units (GRU) or Bidirectional GRUs are used (21, 22). The input and output data for training of these models are the input variable array and the output variable array respectively. The number of epochs is set to 100 for greater accuracy. These models were also implemented for both one day and two days in advance forecast tasks.

The main difference between the models is that the Bidirectional GRU is trained with sequences in both directions, which can help the model to capture context information from both past and future time steps (23). The GRU training function defines a sequential model with one GRU layer with a specified number of timesteps, a dropout layer to reduce overfitting (dropout value = 0.2), a dense layer with the number of classes in the target variable, and an output softmax activation function. The model is compiled with the Adam optimizer, categorical cross-entropy loss function, and categorical accuracy metric. It then trains the model on the training data, saves the model, and plots the training loss. The BiGRU training function defines a similar model with one bidirectional GRU layer. The rest of the model architecture is the same as the GRU model. This model is also trained, saved, and the training loss is plotted. The evaluation metrics for comparing these models on prediction of COVID-19 for one and two days in advance is given below:

Evaluation Metrics:

Upon testing these models, we get four properties of each one of them- accuracy, f1score, precision and recall (24)- which are used to compare the performance of these models for the mentioned diseases. All these parameters are calculated with weighted average. These terms are briefly explained as follows:

- Accuracy: As a heuristic, or rule of thumb, accuracy can tell us immediately whether a model is being trained correctly and how it may perform generally.
- Precision: Precision helps when the costs of false positives are high. It helps calculate how often the models are correct in their predictions.
- Recall: Recall helps when the cost of false negatives is high. A false negative has devastating consequences. When false negatives are frequent, you get hit by the thing you want to avoid.
- F1 score: F1 is an overall measure of a model's accuracy that combines precision and recall, in that weird way that addition and multiplication just mix two ingredients to make a separate dish altogether.

All the results obtained from the machine learning models and the performance metrics were tabulated and compared.

Results

The research based on the prediction of COVID-19 using deep learning as well as classical machine learning models yielded results that were better than expected. The training set, comprised a two million values dataset which includes the symptoms, test result and other miscellaneous conditions of COVID-19. About 80% of the dataset was used for training the models whereas the rest 20% was for testing. The first set of results depict classical machine learning models that were used to forecast COVID-19 one and two days in advance based on the various symptoms.

Performance Metrics	AdaBoost	Logistic Regression	Random Forest
Accuracy	0.355	0.355	0.353
Precision	0.137	0.137	0.141
F1 Score	0.189	0.189	0.184
Recall	0.355	0.355	0.353

Table 2: Performance of classical models for prediction of Covid-19 one day in advance

Performance Metrics	AdaBoost	Logistic Regression	Random Forest
Accuracy	0.357	0.357	0.356
Precision	0.137	0.137	0.132
F1 Score	0.191	0.191	0.187

Recall	0.357	0.357	0.356
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Table 3: Performance of classical models for prediction of Covid-19 two days in advance

The results generated are low for all the models, mainly precisions and F1score. The accuracy and recall are equal since the recall value is the weighted-average recall. The lower precision measures the proportion of true positives among all examples identified by the model. There is almost little to no difference between the metrics data for one and two days in advance. All of the models having similar results indicate that they are equally unsuitable.

Upon evaluating the performance, using classical machine learning models to predict COVID-19 one or two days in advance is not the best choice because they will most likely generate unreliable results due to sensitivity to outliers or complexity of the disease spread. The next set of results contain functions with recurrent neural networks that are unidirectional GRU and bidirectional GRU. They were also used to forecast COVID-19 one and two days in advance based on the various symptoms. The training loss for the models has been represented. The graphical representation for GRU shows that the model loss is largely reduced at first then begins to decrease steadily with some fluctuations whereas in bidirectional GRU, the model loss decreases rapidly initially then steadily reduces with minimal fluctuations.

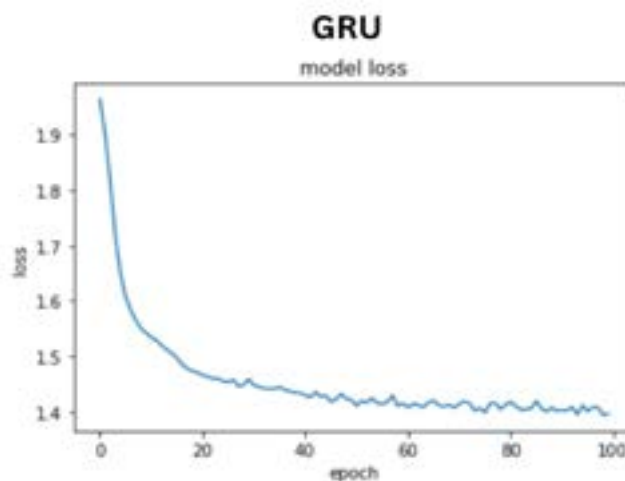


Fig 1: Graphical representation of rapidly decreasing model loss for unidirectional gated recurrent units

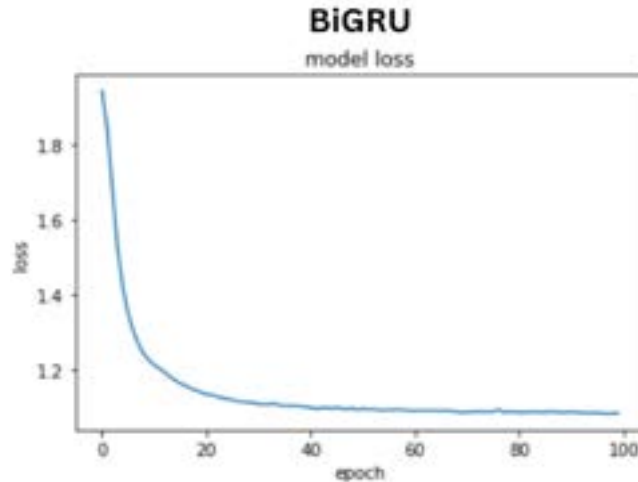


Fig 2: Graphical representation of rapidly decreasing model loss for a bidirectional gated recurrent units

Moreover, the accuracy for GRU is 0.808 while that of the biGRU is 0.992 which is close to 100%. The value of precision and recall is high as well. The calculated F1 score is 0.982 extremely high compared to other machine learning models. Increasing the number of days to forecast in advance decreases the model loss fluctuations in the latter half. The results show that using gated recurrent units (GRU) and bidirectional gated recurrent units (biGRU) are definitely the best choice for prediction of COVID-19 with maximum accuracy and the least training loss.

Conclusion

Based on the results of this research paper, it can be concluded that deep learning models are more effective in predicting COVID-19 one or two days in advance than classical machine learning models.. These models can analyze large amounts of medical data and can provide accurate predictions based on patient data.

Since the performance of classical machine learning models was found to be less than average, we can determine that there is still a lot of room for improvement. In particular, the study highlighted the need for better data preprocessing techniques and feature engineering methods to improve the performance of these models. Furthermore, the use of recurrent neural networks in the form of unidirectional GRU and bidirectional GRU enhances the accuracy of the models while also giving least model loss during training. Overall, the results of this research paper indicate that deep learning models have the potential to become an important tool in predicting various diseases. Further research is needed to validate these results and to explore additional applications of deep learning in the field of medical diagnosis and disease prediction (25).

In conclusion, this research paper has demonstrated the potential of machine learning algorithms in predicting and detecting COVID-19 using patient data. The findings indicate that these algorithms can effectively identify individuals at risk of developing these conditions,

allowing for early intervention and treatment. Moving forward, we hope to explore more powerful models to further improve the accuracy and reliability of our predictions. Additionally, we plan to expand our analysis to other health and disease datasets to investigate the potential of machine learning in improving diagnosis and treatment across a range of medical conditions. By continuing to refine and apply these algorithms, we believe that we can make significant strides in improving public health outcomes and advancing the field of healthcare research.

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To Be a Mature Mortal and an Immature Immortal By Congran Yang

Does dream weigh more than duty? William L. Moran states that the transformation of Enkidu from wild to civilized showed his attainment of wisdom (Moran 203). After meeting with Shamhat, Enkidu is civilized and can no longer live with animals (Foster 3). Being civilized is often seen as a sign of maturity, which has often been directly related to wisdom. However, this social norm is only a result of the general trend in which more people decide to be mature. Gilgamesh should be revered for becoming a mature mortal and taking up responsibilities, but the prince Gilgamesh who immaturely dreamed of immortality is equally essential. Building on Moran's point, this great document of humanism, marked by Gilgamesh's true wisdom should not be limited to accepting his mortal identity, but is his realization that he can still strive for immortality, to recognize his other two-thirds immortal identity. Striving for an impossible goal is where the human spirit shines and echoes in every individual's life as a common note.

Moran's comment in "*The Epic of Gilgamesh: A Document of Ancient Humanism*" suggests that Gilgamesh gains true wisdom because he recognizes human limitations and values (Moran 215). Regretting the immortal plant being eaten by the snake, Gilgamesh understands human fragility and no longer avoids death. Moran pays attention specifically when Gilgamesh is weeping and says "I should have turned back" (Moran 214), as evidence that he has learned his lesson that he can never achieve immortality through his useless work as partially human. Moran further portrays this wisdom as a timeless theme in the epic. He mentioned the paradox describing Gilgamesh at the end of his adventure, which is "weary but at peace", generalizing his physically weary state and mentally peaceful state due to the true wisdom he learned (Moran 203). Along with Gilgamesh's journey of wisdom in carrying responsibilities, Moran points out his transformation from immature to mature and from a "hero" to an "anti-hero" (Moran 210).

Undoubtedly, Gilgamesh gradually gains wisdom through his adventure by being aware of his responsibilities. Gilgamesh summons the elders of Uruk to declare his ambition of killing Humbaba and bringing a cedar tree back since he longs to make an eternal name for himself (Foster 21). He proposes this trip for the possible reason of helping Enkidu reduce his loss of natural power and win personal fame, which is all individual needs but no good for his community. He ignores the risk of his possible death and neglects the dangers that Uruk will face the situations without a king. As the ruler of a huge city, he is too childish. Nonetheless, he grows after losing the immortal plant and reaching Uruk, "Gilgamesh invites Ur-Shanabi to admire the city and its great walls" (Foster 100). Gilgamesh demonstrates his greatness through the city and the wall he constructed, emphasizing its size and finery. His focus on the city and its walls symbolizes his awareness of the responsibility as a king, in contrast to his earlier depiction as a careless prince who focuses on his deeds instead of the community's interest. In recognizing his king's duty, he becomes wiser, and maturity is shown through his decision to focus on the community.

In addition, another aspect suggesting Gilgamesh's developing wisdom is when he understands the true inescapable fate of mortals – death. Prior to witnessing Enkidu's death,

Gilgamesh persuades Enkidu to come with him to fight the monster Humbaba by stating, “If I fall, I’ll have established my name: ‘Gilgamesh, who joined battle with fierce Humbaba,’ (they’ll say)” (Foster 20). At this point, Gilgamesh plans to be immortal spiritually through his fame. He does not consider death seriously but more a tool to prove his strength, which is a misinterpretation of death. Nevertheless, after Enkidu dies in front of Gilgamesh, he learns the cruelty of this inevitable and irreparable mortal common destiny. He tries to avoid it by seeking immortality physically. Although this flight from fate may be viewed as immature and daydreaming, seeing death objectively is also a form of wisdom. This is the first major shift in his rising wisdom. Likewise, after Gilgamesh fails the sleep challenge, he points out desperately, “Death lurks in my bedchamber, and whenever I turn, there is death!” (Foster 97). Gilgamesh’s immortality bubble bursts. He further realizes death in a deeper aspect and accepts it, presenting elderly-like wisdom, weighing more the features of an “anti-hero” who no longer chases after a magnificent dream.

On the other hand, Gilgamesh does not view his journey toward immortality as an “improper action” as Moran claimed (Moran 214). Grieving not securing the plant, he uses strong rhetorical questions, “For whom, Ur-Shanabi, have my arms been toiling? For whom has my heart’s blood been poured out?” (Foster 100). His confusion about not achieving his goal and the unwillingness to quit his dream raged over him. He shows Ur-Shanabi the wall of Uruk he built because he still hopes to be immortal by making his name great, so he does not entirely accept the result of death or his identity as mortal. Moreover, although Gilgamesh picks up his identity as a mature king, he still retains his identity as an immature prince. The epic ends with almost the same description of Uruk as the beginning, “Go up, Ur-Shanabi, pace out the walls of Uruk [...] the measure of Uruk!” (Foster 100). By intentionally pointing out Ur-Shanabi’s name, which is the only difference compared to the beginning, Gilgamesh is seeking praise to ensure his greatness like a child waiting for approval. This nuance in language implies the inner naïve nature of him and the ‘Prince Gilgamesh’ that has been buried at the bottom of his heart. His immature trait comes from speaking his voice. As long as the dream is held, Gilgamesh will not regret his attempts.

The symbiosis of ‘King Gilgamesh’ and ‘Prince Gilgamesh’ is also foreshadowed in the prologue. Gilgamesh’s lineage is indicated, “Two-thirds of him was divine, one-third of him was human!” (Foster 5). His bloodline emphasizes his dual nature, containing his divine legacy, which grants him extraordinary ambitions in his immortal aspirations to eternal glories, and his mortal limitations, which grounds him in his responsibilities as a ruler. His nature suggests his upcoming internal struggles in valuing mortal duties and immortal dreams, which constitute the major theme in the epic, influencing his decisions alongside the heroic trip. Plus, Gilgamesh “saw what was secret and revealed what was hidden” and “brought back tidings from before the Flood” (Foster 3). He is wise in his insights of death, and in learning the story of the Flood, he makes his civilization great by contributing to cultural heritage, just as a king should endeavor. However, the motivation for this mature outcome results from his immature and relentless pursuit of immortality. Thus, in bearing both his traits of ‘King’ and ‘Prince’, the prologue

encapsulates the central conflict of how Gilgamesh's immortal and mortal natures coexist and shape his journey.

The journey of Gilgamesh is considered a humanistic document not only because of Gilgamesh's growth to maturity, but also the lesson of life choices balancing idealism and realism. The mighty odyssey to seek immortality begins with the naïve goal of leaving an eternal impression in the world, transitions to aiming for immortality physically, and finally changes back to using fame to achieve immortality with a clearer cognition of the chasm between man and god and realizations in picking up his responsibilities as the ruler of Uruk, which shows the accumulated wisdom of Gilgamesh. Simultaneously, Gilgamesh maintains his immature nature despite his mature features holding increasing proportion in deciding his goals for each stage of life. Being a mature mortal can mean abandoning the fantasy world and focusing on the secular world, and being an immature immortal can mean the opposite. They seem like antipodes in that it looks like a strict two-choice question, yet life is inclusive. Regardless, wise people may often choose to be mature mortals, it does not support the theory that mature is right and immature is wrong. Life answers cannot be evaluated. The pursuit of making the impossible possible is the precious essence that thrives in human nature. Therefore, the task should be finding balance in the complexity of human existence but not banishing part of the true self.

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Enhancing Education for Underprivileged Children Through AI-Powered Native Language Learning By Aashray Mathai

Abstract

Education systems in many parts of the world are designed with a primary instructional language that may not be the native tongue of all students. This creates a substantial barrier to learning, particularly for students in underprivileged areas where access to quality education is already a challenge. Language barriers can lead to poor comprehension, decreased engagement, and lower academic performance. Therefore, there is a pressing need for innovative solutions that can bridge these gaps and promote inclusive education.

In recent years, Artificial intelligence (AI) into educational technologies has revolutionized the way students learn, offering personalized and adaptive learning experiences.

The primary objective of this research is to evaluate the effectiveness of an AI-powered application that provides support in native languages for improving academic performance among students from diverse linguistic backgrounds. The study focuses on analyzing the impact of this tool on students' performance in English and Math, comparing different exposure levels to the AI application across various groups and grades.

In the subsequent sections, we will detail the methodology of our study, present and analyze the results, discuss the implications of our findings, and explore potential applications of AI-powered native language learning tools in other underprivileged regions, along with recommendations for educators and policy makers for increased impact.

Keywords: Artificial Intelligence, AI, Inclusive Education, Underprivileged students, Native Language Learning

I. Introduction

1. Background and Significance

1.1. Challenges faced by underprivileged children in education

Education is integral to achieving sustainable development. It is through education that an improved quality of life ensues with people's acquisition of knowledge and skills beneficial to society, at large (Cucio & Roldan, 2020). Inclusive education, however, still remains an issue, especially in India, where there are extensive marginalised communities. These groups include children living in poverty, those from ethnic and linguistic minorities, girls (in some societies), children from remote areas and those with disabilities or other special educational needs (Kumar et al., 2024).

While the Right to Education (RTE) Act and National Education Policy (NEP) aim to educate all children in India (*A Review Of The National Education Policy (NEP) 2020, 2023*), government school teachers face numerous challenges. Lack of adequate training and resources affects their ability to deliver quality education. Nearly half of regular teacher vacancies are filled by ad hoc teachers, impacting stability and continuity in teaching ('Challenges Faced by

Government Schools', n.d.), resulting in a lack of support for the children, causing them to fall behind.

1.2. Importance of education in native languages

More than 40% of children worldwide are schooled in a language they do not understand or speak well (Ross, 2024). Underprivileged children, particularly those from economically and linguistically marginalized communities, face significant barriers in accessing quality education. These children often struggle with the language of instruction in schools, which is typically different from their native language. This linguistic mismatch leads to poor comprehension, lower academic performance, and higher dropout rates. Additionally, socio-economic constraints such as lack of access to educational resources, inadequate school infrastructure, and limited parental support exacerbate these challenges (*Socioeconomic Inequalities and Learning | Unesco IIEP Learning Portal*, n.d.).

Linguistic discordance describes the mismatch between the language of schooling and the language of the home. Learning poverty captures the rate of students per country who are unable to read and understand a simple text by age 10.

Data reveal positive correlation between rate of linguistic discordance in primary grades and learning poverty, showing lower country-level basic literacy outcomes go hand in hand with having more students who are taught in a language not spoken at home.

Using the learners' own language can have a positive effect on learning through the comparison and contrast of languages (Cummins, 2007) and in particular leads to efficient vocabulary learning (Nation, 2001).

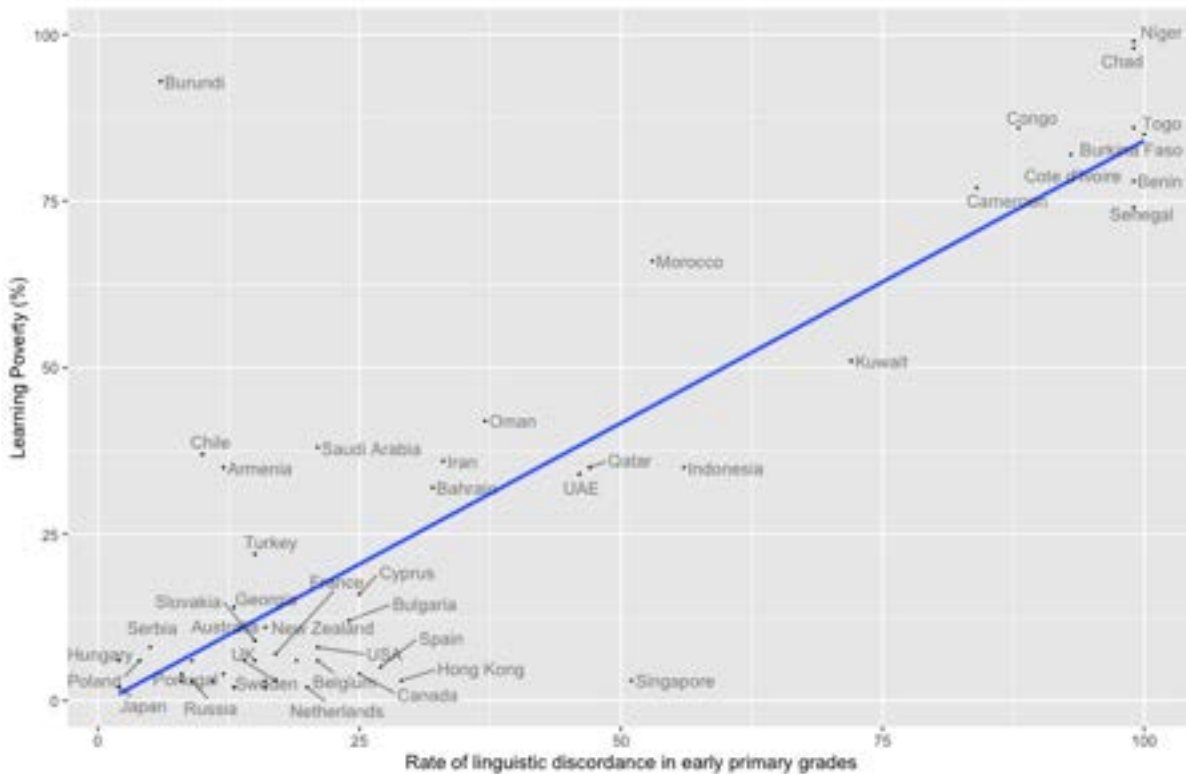


Fig 1: Rate of linguistic discordance in early primary grades

II. Role of AI in Education

2.1 AI's Potential in Addressing Educational Disparities

Artificial Intelligence (AI) has the potential to significantly address educational disparities through various means. AI-driven educational technologies can tailor learning experiences to individual needs, thereby offering personalized learning that traditional methods cannot match. This customization is particularly beneficial for underprivileged students who often face unique challenges.

Personalized Learning: AI can provide adaptive learning experiences that cater to the specific needs, strengths, and weaknesses of each student. This is especially important for students from diverse linguistic and socio-economic backgrounds, as it can adapt the language of instruction to their native tongue, improving comprehension and retention of material. This personalized approach helps in closing the learning gap caused by standardized curricula that may not be suitable for all learners (Milberg, 2024) (Ahmed et al., 2024).

Resource Allocation: AI can help in identifying and addressing resource gaps by analyzing data to determine where resources are most needed. This ensures that educational materials, qualified teachers, and infrastructure improvements are directed towards schools and regions that are most under-resourced, thereby promoting equity in education (Hosseini, 2023) (Ahmed et al., 2024).

Teacher Support: AI can assist teachers by automating administrative tasks, allowing them to focus more on instruction and student engagement. Additionally, AI can provide professional development opportunities, particularly in remote or underserved areas, by offering training and mentorship through digital platforms (Ahmed et al., 2024).

Early Intervention: AI systems can monitor student performance in real-time and identify those who are at risk of falling behind. This allows for timely interventions, such as additional tutoring or tailored learning plans, to support struggling students before they fall too far behind (Ahmed et al., 2024).

Addressing Social and Cultural Bias: AI tools can be designed to be culturally sensitive and can help identify and mitigate biases in teaching materials and assessment methods. This helps create a more inclusive learning environment where all students, regardless of their background, can thrive (Hosseini, 2023).

By leveraging these capabilities, AI can play a crucial role in bridging educational disparities, ensuring that all children, irrespective of their economic or linguistic background, have access to quality education and the opportunity to succeed academically.

2.2. Benefits of AI in personalized learning

Inclusivity in education is about ensuring all learners have access to quality education that is respectful of and accommodates their individual needs. AI has the potential to break down barriers that have historically led to the exclusion of certain groups from effective education (McNulty, 2024).

Language processing tools help break down barriers for non-native speakers (McNulty, 2024). Translation promotes biliteracy development and promotes the acquisition of English (Cummins, 2007)

AI-powered personalized learning offers several advantages, particularly in the context of enhancing educational experiences for underprivileged children. Here are some key benefits supported by research:

Tailored Learning Experiences: AI systems can adapt educational content to meet the individual needs of students, allowing for more effective learning. These systems adjust the pace and difficulty of lessons based on the learner's progress, ensuring that each student receives personalized support that can enhance understanding and retention of information (Laak & Aru, 2024).

Improved Learning Outcomes: Studies have shown that personalized learning platforms can significantly improve academic performance. For instance, adaptive learning systems that tailor instruction to individual learning styles and abilities have been found to increase learning efficiency and scores compared to traditional one-size-fits-all approaches (Laak & Aru, 2024).

Engagement and Motivation: Personalized learning platforms often incorporate interactive elements that can increase student engagement and motivation. By providing content that is relevant to the student's interests and learning style, AI can make learning more enjoyable and stimulating, which can lead to better educational outcomes (Laak & Aru, 2024).

Addressing Educational Disparities: AI has the potential to bridge educational gaps by providing high-quality, personalized education to students in underserved communities. It can offer resources and support that might otherwise be unavailable due to socioeconomic constraints, thus helping to level the playing field for all students (Laak & Aru, 2024).

Scalability and Accessibility: AI-powered educational tools can be scaled to reach a large number of students, making them an effective solution for addressing the needs of underprivileged children. These tools can be accessed via mobile devices, providing educational opportunities to students in remote or rural areas where traditional educational resources may be limited (Laak & Aru, 2024).

By leveraging these benefits, AI can play a crucial role in enhancing education for underprivileged children, offering them personalized, engaging, and effective learning experiences that can help overcome the barriers they face.

2.3. Objectives of the Study

The study aims to evaluate the effectiveness of an AI-powered app designed to enhance education for underprivileged children by providing content in their native languages. The specific objectives are:

Assess the Impact of AI Exposure Levels:

Evaluate how different levels of AI exposure (none, complete, few hours a day) influence the academic performance of underprivileged children.

Compare the outcomes of these groups in terms of language literacy and math skills to determine the most effective level of AI integration in their learning process.

Evaluate the Role of Native Language Support:

Investigate the effectiveness of native language translation and explanations provided by the app in improving comprehension and retention of educational content.

Measure Improvements in Educational Outcomes:

Conduct monthly assessments to track the progress of students in both language literacy and math skills.

Analyze the data to identify trends and significant improvements over the study period.

Provide Recommendations for Educators and Policymakers:

Offer evidence-based recommendations on how educators and policymakers can leverage AI to address educational disparities.

Suggest strategies for implementing AI-powered learning tools in under-resourced schools to enhance educational outcomes.

III. Literature Review

3.1. Theories and Models of Language Acquisition in Children

Nativist Theory:

Noam Chomsky introduced the nativist theory, suggesting that children are born with an innate ability to learn language through a hypothetical module in the brain known as the Language Acquisition Device (LAD). This theory emphasizes the universal grammar underlying all human languages, which children instinctively understand and use to learn their native language (Skinner, 1992).

Chomsky's idea of an innate LAD supports the use of AI to facilitate natural language learning processes. The app can tap into children's innate language learning abilities by providing structured, yet intuitive, language learning tools.

Social Interactionist Theory:

Lev Vygotsky and Jerome Bruner are key figures in the social interactionist theory, which highlights the importance of social interactions in language development. According to this theory, language acquisition is driven by the child's desire to communicate and interact with others. Caregivers and peers provide the necessary social context and feedback for language learning (Vygotsky, 1978).

This theory emphasizes the importance of social interactions and the role of caregivers and peers in language development. AI-backed apps which provide native language support and interactive learning experiences while mimicking the role of a tutor, aligns well with this theory by creating a socially engaging and supportive learning environment (Skinner, 1992).

Connectionist Models:

Connectionist models, influenced by advances in computational modeling, suggest that language acquisition results from the formation of neural connections in the brain. These models emphasize the role of neural networks and parallel processing in learning language patterns. Children learn language by being exposed to linguistic input and forming connections based on the frequency and patterns of language use (Brown & Chater, 2004).

The AI-powered app's ability to provide consistent and varied language input in the child's native language supports these models by reinforcing learning through frequent and diverse interactions.

These theories and models provide a comprehensive understanding of how children acquire language. Each theory offers valuable insights into the complex interplay of innate abilities, environmental factors, social interactions, and cognitive development in language learning. Integrating these perspectives can guide the creation of AI-powered educational tools aimed at enhancing language acquisition in children, especially those from underprivileged backgrounds

3.2. Importance of native language in early education

Cognitive and Academic Benefits:

Early education in a child's native language significantly enhances cognitive development and academic performance. Research shows that children grasp concepts better and retain information longer when taught in a language they fully comprehend. This foundational understanding facilitates the learning of additional languages later on (Cummins, 2000).

Social and Emotional Development

Learning in their native language helps children maintain cultural identity and strengthens family bonds, fostering a sense of belonging and emotional security, crucial for healthy development (Skutnabb-Kangas, 2000).

Bridging Educational Gaps

For underprivileged children, native language education bridges significant educational gaps by ensuring language barriers do not hinder their understanding of core subjects. This leads to improved academic outcomes and reduced dropout rates (Thomas & Collier, 2002)

Role in Multilingual Education

Educating children in their native language provides a strong linguistic foundation, facilitating the acquisition of new languages and supporting multilingual education, beneficial in a globalized world (Cummins, 2000).

3.3. Previous research on AI and language in education:

‘A Systematic Review of Artificial Intelligence in Language Education from 2013 to 2023: Current Status and Future Implications’ (Zhu & Wang, 2024)

This paper reviews AI applications in language education over the past decade. It highlights key trends, including the growth of AI-driven personalized learning tools,

intelligent tutoring systems, and conversational AI. The review emphasizes AI's role in enhancing language acquisition through adaptive learning experiences and providing real-time feedback. The paper also discusses future implications, suggesting continued integration of AI could bridge educational disparities and improve outcomes for diverse learners.

‘A Review of AI Teaching and Learning from 2000 to 2020’ (Ng et al., 2023)

Focus Areas: AITL primarily centered around computer science education at the university level before 2021. Teaching AI was less common in K-12 classrooms due to a lack of age-appropriate teaching tools. **Pedagogical Approaches:** Educators adopted collaborative project-based learning, including activities like software development, problem-solving, tinkering with robots, and gamified elements. However, many activities required programming prerequisites and did not scaffold students’ AI understanding. **Shift to Interdisciplinary Design:** Recent years saw a shift from technology-oriented teaching to interdisciplinary approaches. Suitable teaching tools and pedagogical support contributed to this shift. **Global Initiatives:** AI literacy has been included in educational standards and strategic initiatives worldwide. These findings provide a foundation for educators and researchers to design effective pedagogical strategies and curricula, preparing students to be responsible citizens in today’s growing AI-driven economy.

‘A Bibliometric Analysis of Artificial Intelligence in Language Teaching and Learning’ (Ma et al., 2024)

Research Trends and Current Status: The study analyzes AI’s impact on language teaching and learning. It identifies influential sources, institutions, authors, and countries. AI research in this field is rapidly growing, with significant potential. **Evolution of AI in Language Education:** Research predominantly focuses on refining technological solutions. Empirical studies explore AI applications in language education. Interest lies in AI’s effectiveness for language listening, speaking, reading, and writing. **Challenges and Gaps:** Concerns include academic integrity, content authenticity, bias, privacy, and environmental impact. Solutions and regulatory frameworks are lacking. **Future Directions:** Encourage more empirical research on AI’s specific language applications. Develop effective pedagogical approaches. Address concerns related to AI utilization.

These findings outline the current landscape of AI in language teaching and learning, highlighting both its opportunities and challenges for future research and implementation.

‘Artificial Intelligence Technologies and Applications for Language Learning and Teaching’ (Son et al., 2023)

AI Technologies in Language Education: The study covers various AI technologies used in language learning and teaching. These include natural language processing (NLP), data-driven learning (DDL), automated writing evaluation (AWE), computerized dynamic assessment (CDA), intelligent tutoring systems (ITSSs), automatic speech recognition (ASR), and chatbots.

3.4. Educational Challenges in Underprivileged Areas

3.4.1. Socioeconomic and linguistic barriers:

“A Review of the Literature on Socioeconomic Status and Educational Achievement” (Broer et al., 2019):

This review focuses on socioeconomic status (SES) and its related constructs, the association between SES and educational achievement, and differences among educational systems. It evaluates commonly-used proxy variables for SES in education research and explores changes over time. The study emphasizes that while family SES consistently correlates with student achievement, the magnitude of this relationship varies across social contexts and education systems.

“Language and Socioeconomic Disadvantage: From External to Internal Factors in Language Delay” (Roy et al., 2014):

Funded by the Nuffield Foundation, this research investigates language delay in socioeconomically disadvantaged preschoolers. It aims to understand external and internal factors involved in language delay, using measures with varying social bias. The study sheds light on the complex interplay of socioeconomic and linguistic factors in early language development.

“Intersectionality of Disability and Cultural/Linguistic Diversity” (Kaplan & Celik, 2023):

Although not exclusively focused on socioeconomic barriers, this literature review explores the experiences of parents at the intersection of cultural and linguistic diversity and having a child with a disability. Understanding these dynamics is crucial for providing equitable access to education and support.

“Overcoming Language Barriers: Lessons Learnt from Migrant Children” (Yu & Shandu, 2017):

While considering factors beyond socioeconomic status (SES), this review examines strategies to overcome language barriers in education. It highlights the importance of addressing linguistic diversity to enhance educational effectiveness.

“Families, Language, and Equal Opportunities: Identifying Factors in Home Learning Environments” (Breeze & Halbach, 2024):

This conceptual overview discusses factors affecting language and literacy development in children aged 0–3. It also reviews programs designed to enhance the home learning environment, emphasizing the role of language in equal opportunities.

3.4.2. Existing Interventions:

Financial Support Programs:

Scholarships and Grants: Research shows that scholarships and grants significantly increase enrollment and retention rates among students from low-income families. For example, a

study by Dynarski (2003) found that providing financial aid to low-income students can reduce dropout rates by up to 20% (Dynarski, 2003).

Conditional Cash Transfers (CCTs): Evaluations of CCT programs, such as those in Latin America (e.g., Mexico's Progresa/Oportunidades), demonstrate that these programs increase school attendance and completion rates. Fiszbein and Schady (2009) reported positive effects on school enrollment and reduced child labor (Fiszbein et al., 2008).

School Infrastructure Development:

Building and Renovation: The World Bank (2018) highlights that investments in school infrastructure, particularly in rural and underserved areas, lead to improved educational outcomes by providing a conducive learning environment (World Bank, 2018).

Access to Technology: Studies indicate that integrating technology in classrooms can enhance learning outcomes, particularly in under-resourced schools. For example, Banerjee et al. (2007) found that computer-assisted learning programs improved math scores among Indian students (Banerjee et al., 2007).

Free or Subsidized Meals:

Research from the World Food Programme (2013) shows that school meal programs improve attendance, concentration, and academic performance. A study in Kenya found that providing school meals increased attendance by 30% (Vermeersch & Kremer, 2004).

Transportation Services:

A study by Dewees (2000) found that providing transportation services in rural areas of the United States increased school attendance and reduced dropout rates (Giles, 2014).

Linguistic Barriers:

Dual Language Instruction: Research indicates that bilingual education programs support better academic outcomes for language minority students. A meta-analysis by Rolstad, Mahoney, and Glass (2005) concluded that bilingual education programs are more effective than English-only programs in promoting academic achievement (Rolstad et al., 2005).

Language Support Services: Studies show that employing bilingual teachers and aides improves comprehension and academic performance. For instance, a study by Umansky and Reardon (2014) found that bilingual instruction led to higher literacy rates among English learners in California (Umansky & Reardon, 2014).

Teacher Training and Professional Development:

Culturally Responsive Teaching: Ladson-Billings (1995) emphasizes the importance of culturally responsive teaching in engaging students from diverse linguistic backgrounds.

Professional development programs that train teachers in these methods have been shown to improve student engagement and performance (Ladson-Billings, 1995).

Language Development Programs: Research by the National Literacy Trust (2017) suggests that continuous professional development in language teaching enhances teachers' effectiveness in supporting language learners (Clark & Teravainen, 2015).

Curriculum and Materials Development:

Multilingual Resources: Studies indicate that providing educational materials in students' native languages enhances comprehension and retention. For example, Cummins (2000) argues that students learn best when they can relate new information to their existing linguistic knowledge (Petrovic & Olmstead, 2001).

Inclusive Textbooks: Research shows that inclusive textbooks reflecting students' cultural and linguistic backgrounds improve engagement and learning outcomes. A study by Sleeter (2011) found that culturally relevant curricula boosted minority students' academic achievement (Sleeter, 2011).

Community and Parental Engagement:

Parental Involvement Programs: Studies highlight the positive impact of parental involvement on student achievement, particularly for language minority students. For instance, a study by Jeynes (2005) found that parental involvement significantly improves academic outcomes across different ethnic groups (Jeynes, 2005).

Community Partnerships: Research by Epstein and Sheldon (2002) demonstrates that community partnerships enhance educational support for students, leading to better academic performance and school attendance (Epstein & Sheldon, 2002).

Language Assessment and Support:

Diagnostic Tools: Research underscores the importance of accurate language assessments in identifying students' needs and tailoring instruction accordingly. For example, a study by García and Kleifgen (2010) emphasizes the need for reliable assessment tools to support bilingual education (García & Kleifgen, 2010).

Remedial Programs: Studies show that remedial language programs help bridge learning gaps for language learners. For instance, August and Shanahan (2006) found that targeted language interventions significantly improved literacy skills among English language learners (August & Shanahan, 2017).

These interventions collectively contribute to more equitable and inclusive education, helping to bridge the gaps caused by socioeconomic and linguistic challenges.

IV. Methodology

4.1. Research and Design Considerations:

4.1.1. User-Centric Design:

User Interface (UI) and User Experience (UX): Studies highlight that interactive and visually appealing designs are essential in keeping children engaged (Hirsh-Pasek et al., 2015).

Children are naturally drawn to colorful, dynamic, and interactive elements, which can make learning more enjoyable and less of a chore.

The MPowerEd app has a colorful background and animations of children to attract young minds.

Simplified Navigation: Research indicates that children benefit from simple and intuitive navigation structures that reduce cognitive load (Kalyuga, 2011).

The app has been designed with a simple linear flow and a single-level navigation menu.

Accessibility: Applying universal design principles ensures that learning apps are accessible to children with disabilities, providing features like text-to-speech, adjustable text sizes, and high contrast modes (Burgstahler, 2015).

The app has text-to-speech and a special sound at button press to indicate action.

4.1.2. Content Research, Curation and Relevance:

Quality content that is relevant to the curriculum helps in contextualizing learning, making it easier for children to retain information and transfer knowledge to different contexts (Brown & Chater, 2004).

Content for the app was researched extensively based on the Telangana State Secondary School Curriculum (TS SSC). Daily Tasks and Tests were based on the lesson plans for the respective grades. The grade level content was based on the overall TS SSC learning outcomes of the year.

4.1.3. Performance and Scalability:

Response Time: Studies emphasise fast response times are essential for maintaining the attention and engagement of children. Children, especially younger ones, have shorter attention spans and are more likely to abandon an app that does not provide a seamless experience (Hirsh-Pasek et al., 2015).

Reliability: Reliable performance ensures uninterrupted access to learning content, preventing disruptions that could hinder children's progress and focus (Svendson et al., 2017).

Scalability: As educational apps gain popularity, they must handle increasing numbers of concurrent users without degrading performance. Scalable infrastructure ensures that the app remains functional and responsive, even during peak usage times (Dabbagh & Kitsantas, 2012).

Multiple Python libraries were considered and evaluated for reliability and response time:

Function	Library evaluated	Result
Scanning	Pytesseract	Library dependencies

		clashing
	Tesseract-OCR	Too many fails
	PyOCR	Not language reliable
	Google Vision API	Selected
Language Detection	Google Vision API	Selected
	MS Azure Text Analytics API	Little support for indian language
Translator	Google Translate	Selected
	Deep Translator	Not all languages reliable
Text-To-Speech	TTS	Slower
	gTTS	Selected
Text-To-Image	ChatGPT 4	Selected but too expensive
Explain	ChatGPT 3	Low Indian language support
	ChatGPT 3.5 Turbo	Selected, better responses
Testing	OPExams	Selected, cheapest
	OpenAI GPT-3	Low indian language support

4.1.4. Adaptive Learning Technologies:

Scalable apps can effectively implement adaptive learning technologies, which personalize the learning experience based on individual progress and needs. This personalization is shown to enhance learning efficiency and outcomes (Corrin & de Barba, 2014).

The app saves test assessment results. Content is served in accordance to the user's progress.

4.2. Key features of the app:

Translation Capabilities:

The app provides translation through two primary methods: image scanning and audio recording.

Image Scanning:

Users can capture an image or upload a saved image for text extraction. The app employs Optical Character Recognition (OCR) technology to detect and convert the text in the image to its original language, which can then be audibly rendered using Text-to-Speech (TTS) synthesis. Users are presented with a list of languages for translation. Upon selection, the translated text is displayed and can also be heard via TTS in the chosen language.

Audio Recording:

Users can record audio, which the app transcribes into text using Automatic Speech Recognition (ASR) technology. The transcribed text can then be translated into another language, displayed on the screen, and optionally converted to audio in the target language using TTS.

Explanation of Text:

The app provides explanations for the text obtained through scanning or recording. These explanations are available both in the original language and the translated language, in both text and audio formats, enhancing comprehension and learning.

AI-Based Question Generator:

The app incorporates an AI-driven question generator that formulates questions and answers based on the scanned or recorded text. This feature promotes critical thinking by encouraging users to engage deeply with the content.

Task Feature:

The app includes a daily task feature that assigns users tasks appropriate to their grade level and progress. Each day, users receive a new task, with a total of 30 tasks provided per month. These tasks are designed to reinforce learning and ensure continuous engagement with the material.

Testing Feature:

At the end of each month, the app administers a test based on the daily tasks completed by the user over the month. The results of these tests are recorded and saved, providing a measure of the user's progress and performance over time.

The AI-based self-learning app is equipped with advanced translation capabilities, an intelligent question generator, and structured task and testing features. These components collectively provide a comprehensive and adaptive learning experience, leveraging the latest technologies in AI and educational psychology to support effective self-directed learning.

4.3. Participants:

4.3.1. Explanation of the three groups and their levels of AI exposure

To effectively measure the impact of the AI-based self-learning app on children's educational outcomes, participants will be divided into three distinct groups, each receiving different levels of exposure to the app. This approach allows for a comparative analysis of how varying degrees of interaction with the app influence learning.

	Group A	Group B	Group C
App Usage Training	Yes	Yes	No
Daily Task Taking	Yes	Yes	No
Integrated Learning aided by Teacher	Yes	No	No
School curriculum matches Daily Tasks	Yes	Yes	Yes
Parental Involvement	Yes	No	No
Test Taking Training	Yes	Yes	Yes

By assigning children to these three groups with varying levels of exposure to the AI-based self-learning app, the study aims to evaluate the app’s effectiveness in enhancing educational outcomes. Group A will help determine the maximum potential impact of intensive app use, Group B will show the effects of moderate integration, and Group C will serve as a control to assess improvements against traditional learning methods. This structured approach ensures a comprehensive understanding of how different levels of AI exposure influence learning. The detailed assessment of Group A's task completion and final test scores will provide deeper insights into the app's impact on student engagement and academic achievement.

4.3.2. Selection criteria

Age and Grade Level: Ensure children in all groups are of similar age and grade level to control for developmental differences in learning capabilities.

Socioeconomic Status: Stratify groups to have a balanced representation of various socioeconomic backgrounds to account for environmental influences on learning.

Initial Assessment: Conduct a pre-study assessment to gauge the current academic performance and proficiency levels in the relevant subjects. This can include standardized test scores or teacher evaluations. Categorize children into performance bands (e.g., low, medium, high) to ensure each group has a similar distribution of academic capabilities.

4.3.3. Demographic details of the participants

To ensure a comprehensive understanding of the study’s participants, the following demographic details will be collected and analyzed. This information will help contextualize the results and ensure that the groups are balanced and representative.

Age Range: 6-10 years

Grade Levels: 1st to 2nd grade

Gender: Equal participation

Household Income: very low and low

Primary Language Spoken at Home: selection exists in the app

4.4. Procedure

4.4.1. Daily tasks and features of the app:

For Group A: Daily Task done. Teachers give them an assignment to do more on the same topic, so they will be doing tasks similar to the Daily Task. Users are free to explore the app using any of the other available features.

For Group B: Daily Task done.

For Group C: None

4.4.2. Assessment schedule:

1st of the month, after a month of Daily Tasks on the topic.

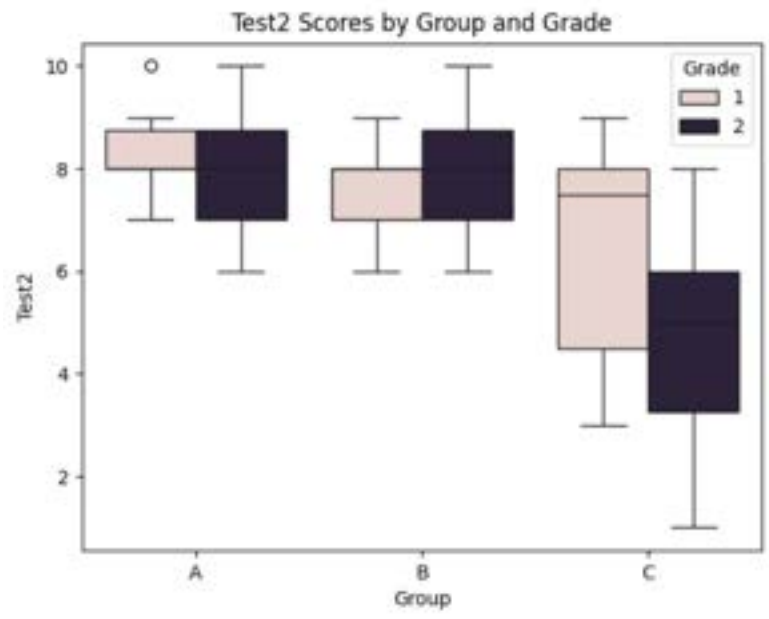
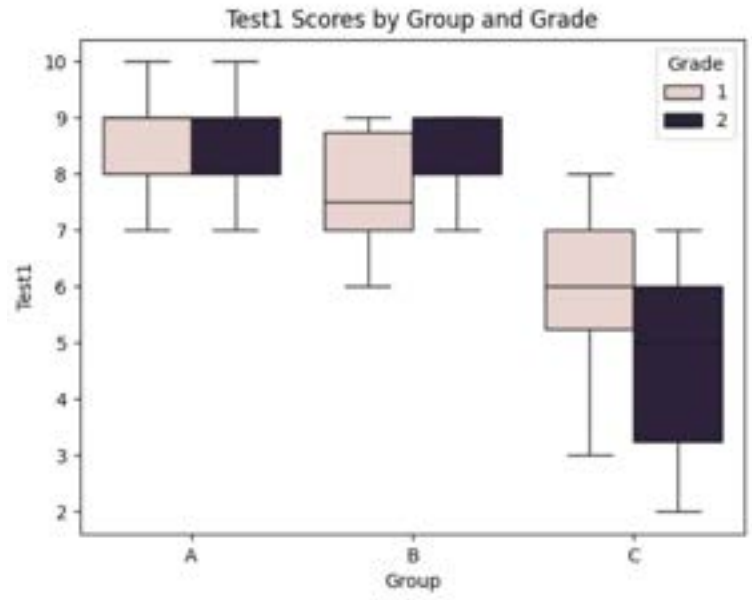
4.5. Data Collection:

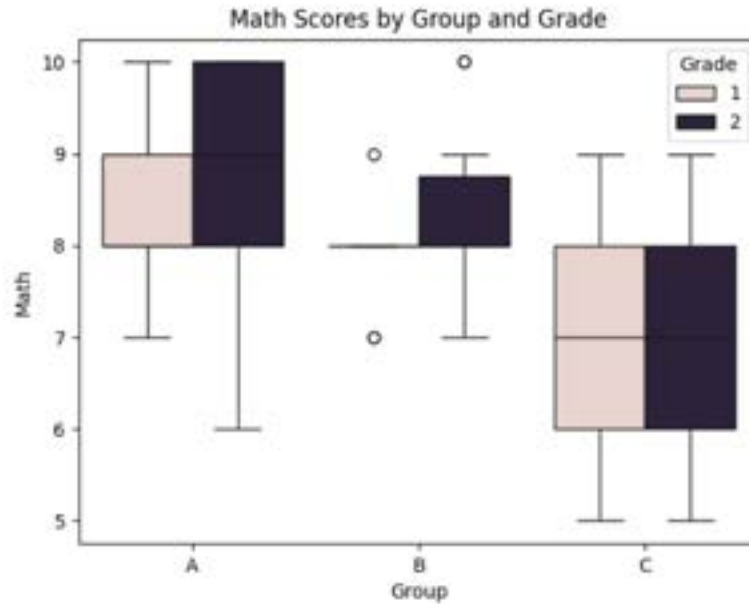
Users get individual accounts when they register into the app. Their Daily Tasks and Assessment scores are recorded and saved in a backend database.

V. Results:

5.1. Mean and standard deviation for each test within each group and grade combination to help in understanding the distribution and variability of scores.

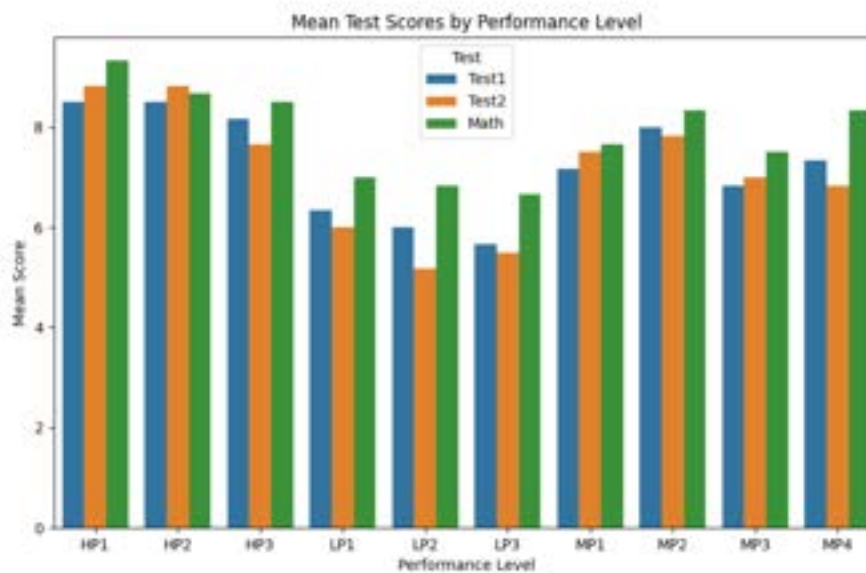
Group	Grade	Test1		Test2		Math	
		mean	std	mean	std	mean	std
A	1	8.6	0.843274	8.2	0.918937	8.5	0.971825
	2	8.3	0.948683	7.9	1.197219	8.8	1.316561
B	1	7.7	1.059350	7.6	0.843274	7.9	0.567646
	2	8.2	0.788811	7.9	1.197219	8.3	1.059350
C	1	6.0	1.632993	6.4	2.270585	6.9	1.370320
	2	4.7	1.636392	4.7	2.213594	6.9	1.370320





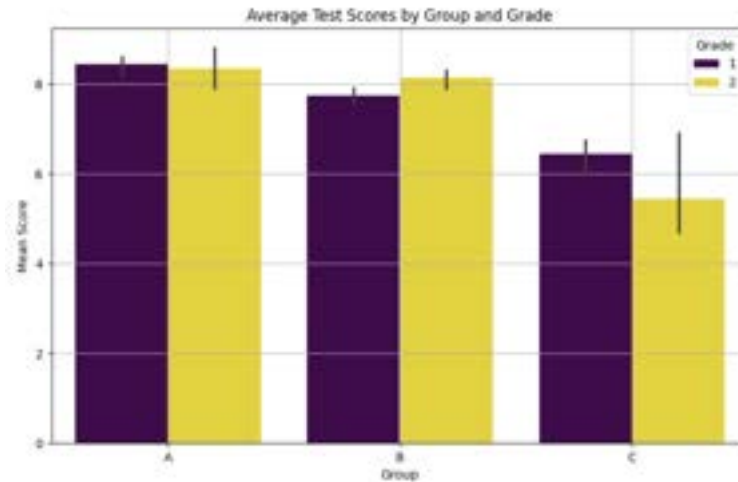
5.2. Mean Test Scores Across Performance Levels:

Performance Level	Test1 mean	std	Test2 mean	std	Math mean	std
HP1	8.500000	1.643168	8.833333	1.329160	9.333333	0.816497
HP2	8.500000	0.836660	8.833333	0.488248	8.666667	1.032796
HP3	8.166667	1.169845	7.666667	0.816497	8.500000	1.378485
LP1	6.333333	2.250926	6.000000	2.366432	7.000000	1.549193
LP2	6.000000	1.673320	5.166667	2.228682	6.833333	0.752773
LP3	5.666667	2.658320	5.500000	2.589980	6.666667	1.505545
MP1	7.166667	1.471960	7.500000	1.224745	7.666667	1.366260
MP2	8.000000	1.264911	7.833333	1.602082	8.333333	0.816497
MP3	6.833333	1.602082	7.000000	1.673320	7.500000	0.836660
MP4	7.333333	1.505545	6.833333	0.488248	8.333333	0.516398



4.3. Average Scores by Group and Grade:

Group	Grade	Test1	Test2	Math
A	1	8.6	8.2	8.5
A	2	8.3	7.9	8.8
B	1	7.7	7.6	7.9
B	2	8.2	7.9	8.3
C	1	6.0	6.4	6.9
C	2	4.7	4.7	6.9



5.4. Testing Scores difference amongst groups:

Analysis Summary			
Comparison	Test1 Diff	Test2 Diff	Math Diff
Group A vs B			
Grade 1	0.9	0.6	0.5
Grade 2	0.3	0.2	0.6
Group B vs C			
Grade 1	1.7	1.5	0.9
Grade 2	3.0	2.5	1.7

Group A consistently has higher average scores compared to Group B in both grades. However, the difference between their scores is relatively small. Group B has significantly higher average scores compared to Group C in both grades. The difference in scores is substantial.

VI. Discussion:

6.1 Interpretation of Results:

Performance Improvement with Exposure:

High Exposure Group (A): This group consistently showed higher average scores across all tests and grades. The high performers (HP1, HP2, HP3) in this group had almost perfect scores, indicating a positive impact of high exposure to educational resources, including native language support.

Medium Exposure Group (B): This group had moderate scores, with a noticeable gap between their performance and that of the high exposure group. High performers in this group did well but not as well as those in the high exposure group.

No Exposure Group (C): This group had the lowest scores, particularly evident in low performers (LP1, LP2, LP3). The scores suggest that lack of exposure correlates with lower performance.

The performance of Group B is closer to that of Group A than to Group C. Group B's average scores are intermediate but much closer to the higher-performing Group A, indicating that medium exposure to educational resources results in performance closer to high exposure, while no exposure leads to significantly lower performance.

Impact Across Subjects:

English vs. Math: All groups showed a trend where Math scores were slightly lower than English scores. This suggests that regardless of exposure, students find Math slightly more challenging than English.

Grade Level Differences:

Grade 1 vs. Grade 2: Scores generally improved from Grade 1 to Grade 2 within each group. The performance gap between Group A and B narrowed slightly in grade 2, but the gap between Group B and C widened, indicating that continued exposure to native language support has a compounding positive effect over time.

Performance Level Analysis:

Low Performers: Low performers in the high exposure group performed better than low performers in the other groups, suggesting that high exposure can elevate the performance of even the lower achievers.

Medium Performers: Medium performers in the high exposure group had scores similar to high performers in the medium exposure group, indicating that exposure can bridge performance gaps.

High Performers: High performers in the high exposure group excelled significantly, while high performers in the no exposure group performed similarly to medium performers in the high exposure group, indicating a substantial impact of exposure on high achievers.

Consistency in Scores:

High Exposure Group: This group showed the most consistency in scores, with less variation between subjects and tests, indicating that high exposure might contribute to more balanced performance across different areas.

No Exposure Group: This group showed the most variation, suggesting that lack of exposure might lead to inconsistencies in student performance.

6.2. Implications for educators and policymakers:

Integration of Native Language Support: Educational policies should prioritize the integration of native language support in the curriculum, especially in regions with diverse linguistic backgrounds.

Resource Allocation: Schools and educational bodies should allocate resources to ensure that even schools with limited funding can provide some level of native language support.

Teacher Training: Teachers should be trained to effectively use AI tools and native language resources to enhance their teaching methods and support students better.

Global Applications: The success of native language support in this study indicates its potential for broader application in other underprivileged regions. Implementing these tools globally can contribute to reducing educational disparities and promoting inclusive education.

6.3. Limitations of the study:

Only 2 grades were studied. Children in higher grades would find it easier to use the app and might be able to find usecases on their own, making their learning journey bigger.

Only 3 tests were conducted. Toughness of the tests was not quantifiable. It would be interesting to find the variation in groups on easier vs harder tests.

Subject tests were not conducted. Native language learning might play a significant role in understanding STEM topics.

Due to the high pricing of ChatGPT-4 Turbo, learning with pictures feature has been disabled. When the pricing becomes reasonable, this feature will be turned on to increase engagement, understanding and retention.

6.4. Areas for future research:

Longitudinal Studies: Tracking student performance over multiple years to understand long-term impacts of exposure.

Diverse Learning Metrics: Including other subject areas and performance metrics to provide a more comprehensive view of student achievement.

Advanced Predictive Models: Utilizing more sophisticated machine learning models to enhance predictive accuracy and uncover deeper insights.

VII. Conclusion:

7.1 Summary of Findings:

Performance Improvement with High Exposure: Students in Group A showed the highest performance across both grades and all subjects. Average Math scores were significantly higher than those of the other groups, indicating that high exposure to native language support enhances students' understanding and retention of complex subjects.

Higher Gains with Medium Exposure: Students in Group B performed better than those with no exposure, and their performance levels were closer to that of Group A than to Group C, suggesting that even minimal degree of exposure is sufficient to make a positive impact.

Challenges without Exposure: Students in Group C consistently showed the lowest performance, indicating that the lack of native language support is a significant barrier to academic success. This highlights the need for educational tools that cater to linguistic diversity.

Grade-Level Insights: The positive impact of native language support was evident in both grades, though it was slightly more pronounced in grade 2. This suggests that early intervention with native language support sets a strong foundation for continued academic success, and that as the child gets older they are better able to use AI to their advantage.

These findings collectively demonstrate the effectiveness of native language support in improving educational outcomes, especially for students from underprivileged backgrounds. The degree of exposure to native language support plays a crucial role in determining the extent of its benefits.

6.2. Recommendations:

Enhance Resource Accessibility: Increase access to educational resources for all students, particularly those in lower-performing groups, to help bridge the performance gap.

Targeted Interventions: Implement targeted interventions for low-performing students (LP) to provide additional support and improve their academic outcomes.

Sustained Support Across Grades: Ensure continuous support as students progress to higher grades to address increasing academic challenges and maintain high performance.

Further Research: Conduct longitudinal studies to track the long-term impact of educational exposure on student performance. Explore additional subject areas and performance metrics for a more comprehensive analysis.

VIII. Final Thoughts on AI and Native Language Learning:

AI tools supporting native language learning improve accessibility and comprehension, crucial for students in underprivileged regions. Native language support helps students understand and retain complex subjects better. This leads to higher academic performance, as evidenced by the significant improvement in test scores for students with high exposure to such tools. They can bridge educational gaps, ensuring equal opportunities for all students regardless of linguistic background and limited resources. AI provides scalable, customizable solutions tailored to diverse student populations. Successful implementation suggests global applicability, especially in other underprivileged regions with long-term benefits including higher literacy rates, better job prospects, and socio-economic development.

Infrastructure and internet access are critical challenges that need addressing for widespread adoption. Ensuring cultural sensitivity and relevance in content is essential for effectiveness. AI-powered native language learning tools have the potential to transform education, especially in underprivileged regions. By making education more accessible and tailored to students' linguistic needs, these tools can significantly improve academic performance and contribute to more equitable educational opportunities globally.

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New Media, the Internet, and Social Capital in Peachtree Corners By Dorie Liu

Abstract

New media, like the Internet and social media, has undoubtedly influenced community participation and social capital. The introduction of the Internet and its potential impacts on community and social capital has been a highly debated topic across the existing literature. Scholars have argued that media consumption has decreased social capital. Other researchers, however, say that the Internet has increased community engagement and, therefore, social capital through its facilitation of information sharing. This paper will analyze how new media might relate to participatory and social capital, specifically in the city of Peachtree Corners in Georgia. Established in 2012, Peachtree Corners is a relatively new city with an innovative and tight-knit community. Various ways in which community members utilize media in this city may contribute to a closely integrated community, including a monthly newsletter, an e-newsletter, and multiple social media platforms. Considering these factors of Peachtree Corners, a study on the diverse relationships between various new media technologies and the city's community capital is valuable to the ongoing debate about internet-based communities and establishes a city-specific case study of how the Internet might impact social capital.

New Media, the Internet, and Social Capital in Peachtree Corners: A Community Case Study

New media, means of communication through digital technology like the Internet and social media, has undoubtedly influenced community participation and social capital. Social capital – the network of relationships among individuals in a community – has been a topic of research from the early 2000s to recent years (e.g.; Wellman, Haase, Witte, and Hampton, 2001; Hampton, Lee, and Her, 2011; Hampton & Wellman, 2021). The debate across the existing literature about the introduction of the Internet to communities and its potential impacts on social capital has developed into two diverging positions. Some scholars argue that media consumption has hindered social capital due to factors like decreased social support and community commitment (Hampton et al., 2011), while other researchers say that the Internet has increased community engagement and, therefore, social capital (Wellman et al., 2001). However, few researchers disagree that new media – i.e., communication technologies that enable online, digital interactions, has changed the idea of community.

The “traditional community” was smaller, and close relations within it led to similar beliefs and backgrounds among a set number of close individuals. However, with the introduction of new media, such as the Internet and social networking sites, there was increased mobility and contact between various communities as relationships were no longer geographically bound, which changed community structures (Hampton & Wellman, 2021). Following that line of thought is where the diverging perspectives emerge. Some scholars believe that the Internet has decreased social capital, while others believe that it has increased it.

In this article, I explore media use in a mid-sized city in Georgia, using interviews and a comprehensive survey of embedded community members in the city to examine the relationship between the usage of new media and social capital in a community. The city of Peachtree Corners's diversity and its basis of technology make it an ideal representation of the relationship between new media and social capital. A study on those specific relationships within the city is valuable to the ongoing debate about internet-based communities and establishes a city-specific case study of how the Internet might impact social capital.

Because technology is always evolving, the question of whether or not community relationships have been weakened or even lost due to the introduction of new media is also evolving. The present study demonstrates the effects of new media on an innovative and diverse community, the city of Peachtree Corners, such as the effects on factors like network capital and community commitment. My findings contribute to the debate about the nature of community and how technological innovations have impacted it.

Literature Review

Network Capital in the Age of New Media. Network capital, and particularly social capital, has been critically examined within new media and community discussions. Social capital encompasses the relations that provide resources, companionship, and information among an individual's social network and community. Social capital also involves participatory capital, which is community involvement in politics and organizations that creates ties between individuals. Greater community commitment results in an increase in participatory capital and, therefore, civic engagement. Some scholars argue that the Internet increases participatory capital because it supplements organizational involvement (Wellman et al., 2001). As such, scholars frame these findings as a positive impact of new media because participatory capital creates ties between individuals that can reflect increases in community resources and social support. However, other researchers assert that the use of social networking services relates to lower social participation in places like neighborhoods (Hampton et al., 2011). They justify these findings by stating how social networking sites allow access to social support outside the community, decreasing reliance on local ties and, therefore, reducing social capital.

Pervasive Awareness and Strength of Social Ties. The introduction of the Internet and new media to communities has created pervasive awareness, the heightened awareness of events due to the visibility provided by the Internet. This concept – that digital communication technologies provide a constant stream of easily accessible knowledge to individuals – has changed the way that communities function. Some scholars argue that pervasive awareness counters the hypothesized loss of social capital observed in recent decades (Putnam, 1995) – creating stronger ties within a community (Hampton & Wellman, 2021). Pervasive awareness stems from the Internet and new media, wherein the relatively new capacity for community members to be in persistent contact with each other may broaden their access to network resources. In the experiment in “Netville,” scholars studied a newly connected neighborhood at the dawn of the internet. Netville is a suburban neighborhood in Toronto, Canada, where most

homes have technology and Internet access through a local high-speed network- a difference from the other existing neighborhoods in North America at the time. It was shown that the Internet helps community ties flourish because it allows communication in and between neighborhoods at a low cost and higher speed (Hampton & Wellman, 2003). In contrast to these claims, work has also suggested that more frequent Internet use may relate to a broader decrease in community commitment – or the attitudes that people have towards their community – potentially due to new media’s ability to increase the number of weak ties within community members’ social networks (Wellman et al., 2001).

The Evolution of New Media. Past scholars have studied whether or not community has been lost due to the introduction of the Internet (Hampton & Wellman, 2021) and found that while the effects of the Internet on social capital are not exactly all positive or negative, community has been changed but never lost. Researchers have also concluded that while the Internet can engage people in antisocial activities, like watching television or gaming online, it can build social capital by facilitating communication (Wellman et al., 2001). Additionally, scholars have investigated neighborhoods with Internet, like “Netville,” to see the effects of Internet use on social capital within a community (Hampton & Wellman, 2003). However, technology is always evolving, which means its influences and effects on community are ever-changing. Peachtree Corners is a city that is highly advanced compared to the 2003 study of the neighborhood of “Netville” in Canada. As a city with all homes connected through the Internet, a study in Peachtree Corners explores the effects of the Internet on a community rather than just one neighborhood- a look at a city full of “Netvilles” after twenty years. The present study investigates the city-specific relationships between new media use and social capital within the Peachtree Corners community. In doing so, it reflects the impacts, interrelationships, and influences of innovative new media and the Internet on network capital, i.e., participatory capital, social support, and civic engagement in an innovative, Internet-based city. This paper will demonstrate the dynamic effects of ever-changing new media on a contemporary and diverse city.

To research these relationships, I propose the following research questions, ultimately asking whether new media (e.g., internet/social media) has become the 21st century’s public square for communities (i.e., social and participatory capital) to develop. Specifically, I ask how the use of new media relates to community participation and social capital and how those Internet-based interactions may influence community relationships.

RQ1: How does new media (e.g., internet/social media) influence (a) community participation (“participatory capital”) and (b) social capital more broadly (i.e., the relationships between community members)?

RQ2: How might Internet-based interactions and communities influence general community engagement, participation, and relationships?

Methods

I investigated media use in a mid-sized city in Georgia to examine the relationship between the usage of new media and social capital in that community. I employed a qualitative method of research that involved interviews and a comprehensive, informal survey of embedded community members in the city. Peachtree Corners, established in 2012, is a relatively new city in a suburb about 45 minutes outside of Atlanta, Georgia, with an innovative and tight-knit community. Peachtree Corners has a population of 42,243 and is diverse, with 47.4% Caucasian, 23.3% African American, 18.1% Hispanic, 9.4% Asian, and 1.9% other. The average family size is 3 people, and the average household income is \$109,062 as of 2020. Along with its diversity, the city focuses heavily on technology and innovation with the development of the Curiosity Lab and Technology Parkway, making it a unique city to investigate new media in. Various media used by community members in this city include a monthly newsletter, an e-newsletter, and multiple social media platforms, which may contribute to a closely integrated but still diverse community.

Procedures for Data Collection. I conducted two structured interviews with the main communications leaders within the city of Peachtree Corners. The first was with “Luke” (pseudonym), the publisher and executive editor of a local magazine. “Luke” is a male who appears to be in his 40s. We met at a local coffee shop. The second was with “John” (pseudonym), a high-ranking communications professional who works for the city of Peachtree Corners. “John” is a male who appears to be in his 30s. We met at the Peachtree Corners City Hall. Both interviews were roughly an hour or more. “Luke” and “John” were both particularly relevant to the present study because of the insight into their current protocols and future goals for media use in Peachtree Corners.

These interviews involved an interview guide with nine main guiding questions to help keep the interviews on track and ensure discussions addressed my research questions. I created the interview guide by developing questions that were related to my main research questions while not explicitly asking them. These questions were designed to provoke thoughtful and detailed answers regarding each individual’s experience working in the communications field, specifically with new media like the Internet and social media. The questions were designed to be neutral to prevent any biased answers and to ensure depth and detail from the respondents about their own experiences. To gather key concepts from the interviews, I jotted down important ideas during the interviews and noted wherever the participant was very engaged or excited to talk about a topic (e.g., relevant observations). Following these two interviews, I transcribed and read through each one to further identify ideas and insights related to my research questions. I highlighted important quotes to use later and developed concept connections that related multiple concepts together.

To measure the effects of new media on participatory capital, I also conducted a qualitative, informal survey of ten community members in the city of Peachtree Corners who were participating in a community event. This took place at a large community event; a summer concert with covers of a famous singer, in the town square area. Over 200 people of all ages,

racess, and genders attended this event. I asked ten different people questions and chose a diverse selection of people of all ages, races, and genders. Participants were asked how they found out about the event, why they were going to the event, and how many community events they had been to in the past year. I jotted down all the answers on my phone and adjusted them for more detail as needed later to gather key concepts and patterns.

Findings

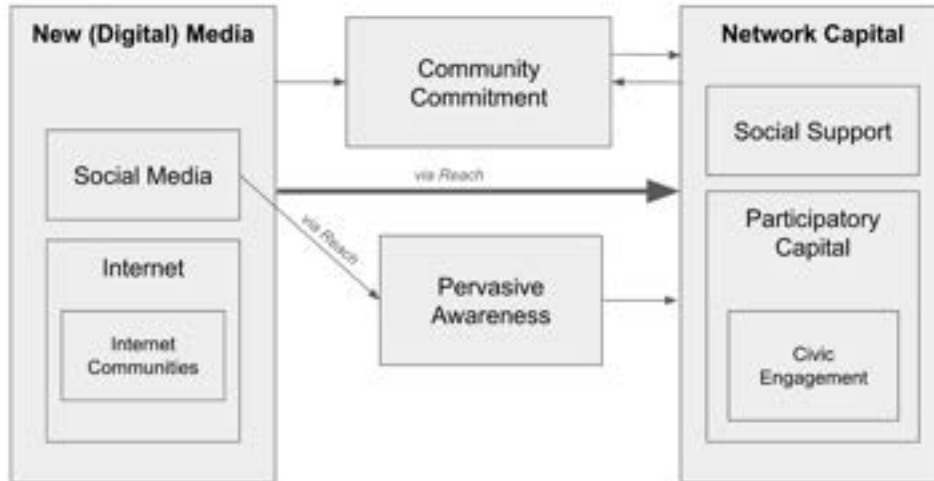


Figure 1: Proposed model highlighting relationships between new media, community commitment, pervasive awareness, and network capital. Arrows signify relationships to and from key variables.

Review of Proposed Model and Findings. The overall relationship studied is how new media might influence network capital through community commitment and pervasive awareness. When new media, which encompasses social media and the Internet, is introduced to communities, it may influence the level of commitment within the community. This can be observed through the possible strengthening or weakening of ties between community members. Also, as new media is utilized more and its reach is increased, it may contribute to pervasive awareness. Network capital is made up of social support, participatory capital, and civic engagement. All factors may be related to the introduction of new media and pervasive awareness.

Participatory Capital and Pervasive Awareness. As new media, like the Internet and social networking sites, are introduced to communities, a new sense of interconnectedness often arises. This is a result of the pervasive awareness, the heightened awareness of events due to the visibility provided by the Internet, that comes with posting updates via new media frequently. The facilitation of information sharing undoubtedly has impacted communities, but the question is how. How does new media influence community participation? Findings from the interviews

and survey may suggest that new media is employed in Peachtree Corners to increase participation within the community (see Figure 1).

For example, in the second structured interview, John, a high-ranking communications professional in the town of Peachtree Corners, spoke in depth about his strategy for advertising city events through various new media.

“In the city, we have a Twitter account, an Instagram account, a Facebook account, and a LinkedIn account. And then, from a daily basis, there's [...] advertising [and] public notices, we have to put news out on the website. All of that's important.” (John)

He utilizes an e-newsletter to send out information about all community events and new businesses, and almost 7,000 people have registered for it. As Peachtree Corners primarily communicates through new media, it supports the idea that it is an internet-based community. John also described an extremely successful partnership with a large news network based in the Atlanta metropolitan area last year. The partnership involved promoting local concerts and events through online media, reaching over a million engagements on the campaign.

“... more people came out to those concerts last year than had come the year before, the year before that [...] the reach was over a million. [...] So that was a huge success, working and moving more into that online market.” (John)

John also discussed the development of an app for the Peachtree Corners community. He was eager to share the possibilities of the app, which would involve social media posts, news, information, events, a shared calendar, and live-streaming features.

“After the event, if you're a registered user, maybe you can do that review type thing, almost like a Yelp, just on the events and things that are going on in the city. So we're trying to find a way to bring the public in, right? To make them part of it.” (John)

John noted that because of this newly developed app, he expects that the people who do not come to council meetings will watch the live streams. Additionally, John hopes that if information on events is easy to access, more people will be able to participate.

“I'm trying to find ways to reach out to people to get them to be part of the community... building community is hugely important for me.” (John)

As the app is still in development, the results are not 100% accurate, but with his experience in communications and media, John is hopeful for the effects of the new app.

The qualitative survey of community members in the city of Peachtree Corners at a community event showed that 70%, seven out of ten, of the people surveyed found out about the

event through new media – either Instagram, Facebook, or the city website. As it was a diverse group of people surveyed, the ages ranged and often reflected which media they found the event through. John also discussed this diversity by describing the various media his team uses to reach as many individuals as possible.

“Now that everything's gone online, it's a little harder because there's so many options [...] the potential to reach more people is higher because there's more people that do all these different things online.” (John)

“So we're looking for younger families who have younger kids. How do I target them? [...] They are more Instagram. If I want to reach the 40 and 50-somethings, it's more of a Facebook play.” (John)

Four of the seven people who found the event through new media found it through Instagram and were in their 20s or early 30s. Two others were in their late 30s to 50s and found it through Facebook. The last one was in their 60s, and found it through the city website. These findings reflect that different types of new media reach different audiences and that the evolution of media comes with certain challenges in reaching a large number of people due to those differences. Overall, the constant updates and advertisements put out on various social media by the Peachtree Corners Council resulted in an increase in attendance which is in line with the idea of pervasive awareness.

Social Support and Community Commitment. Relationships between individuals in a community are formed through friendships, events, mutual interests, etc. However, the introduction of new media and the Internet has changed the dynamic of ties within communities in the 21st century (Hampton & Wellman, 2003). New factors like the Internet, Google, and social media make it easy for individuals to access information outside of their traditional community network, and many scholars assert that this proves that new media decreases social support and community commitment within communities. However, with the evolution of media and how it can be used, there are new ways that new media can impact community relationships. This brings forward the question: How might Internet-based interactions and communities influence general community engagement, participation, and relationships? Findings from the interviews and survey may portray that community members use forms of new media to foster and strengthen relationships within a community and, therefore, increase social support and community commitment (see Figure 1).

In the first structured interview conducted with Luke, the publisher and executive editor of a local magazine, he discussed his use of the magazine and various social media sites like Instagram and Facebook to advertise events. He also spoke about his sponsorship of events that lack funding within the community, which gets the events free advertising in magazines and on

social media and donations. For example, they donated to and advertised for the Gwinnett Asian American Student Association Gala.

“We found the events that we liked that either have no funding or something like that we've stepped in to help them with that [...] I will be a cheerleader for them because they're doing good in the community.” (Luke)

These sponsorships show an increase in social support within the community because of how one group helps another. This finding also relates to how one group can use new media to help another, strengthening those social ties within the community and, therefore, facilitating network capital.

John, in the second structured interview, continued expanding on the development of a new app and expressed excitement for the idea of user-generated media, like a community calendar, and how it would connect the community in a unique way.

“When you pull up your app, you don't just have the City of Peachtree Corners, you have anything that a user has submitted, anything that a restaurant has submitted, or a store, if they have any kind of event going on. So now when you go on there, you have everything, hopefully, that's going on in the city because that doesn't exist right now.” (John)

User-generated content would develop connections between community members, strengthening those ties, and John believes individuals will support each other because they have access to information about various events. John hopes that the app and turning that technology into a benefit for society will combat how communication technology has weakened the community.

“So how do we take what we have and what has been a, to some extent, a degradation of communication in society and turn it into a positive and a benefit for society? [...] we have to find a way to do that.” (John).

The qualitative survey of community members in the city of Peachtree Corners at a community event showed that 40% (4/10) of individuals surveyed stated they normally go to similar events and have gone multiple times in the past year. 30% (3/10) stated they have been to a similar event twice in the past year. Out of these three, two found out about the event through social media: Instagram and Facebook. 30% (3/10) stated that it was their first time at a Town Center event, and one out of the three stated that they do not normally come to events like these. Out of the three first-timers, two found out about the event through social media: Instagram and Facebook. The success of the event surveyed reflects the loyalty of community members and the impact of advertising through new media like social media.

Discussion

Concerns have been raised about the possible weakening and even loss of community due to the introduction of new media. As technology is ever-changing, its relationships to factors within the community will evolve as well. The results of this analysis demonstrate the potential influence of new media on an innovative and diverse community, the city of Peachtree Corners.

A major factor in a community's network capital is participation, e.g., participatory capital. The findings of both structured interviews and a comprehensive survey of community members portray that new media may positively influence participatory capital within a community like Peachtree Corners by facilitating information sharing and increasing the reach of advertisements. The city's partnership with a large news network to promote local events gained over a million engagements and resulted in record-high attendance at the following community events. This finding supports the existing notion that the Internet increases participatory capital because it complements organizational involvement (Wellman et al., 2001). The results also show how the use of new media in Peachtree Corners may reflect how new media leads to pervasive awareness via accessible communication and access to information, backing the notion that the Internet helps community ties flourish by facilitating communication (Hampton & Wellman, 2003). Findings show that communication professionals hope for the development of a city app to bring growing community participation through easy access to information on events with features like a shared calendar. Surveys from a community event also displayed that a majority of people surveyed discovered the event through new media like social media and a city website. Together, these findings challenge the perspective that social capital has been completely lost due to the rise of new media (Putnam, 1995).

Other factors that reflect the interconnectedness of a community are social support and community commitment, both of which are related to general community engagement and relationships based on my findings. The outcomes of the structured interviews and qualitative survey of community members demonstrate how new media can be used by one group to help another, strengthening those social ties within the community and, therefore, increasing social support and network capital. Strong relationships are formed within Peachtree Corners via the assistance of one another, especially through actions like helping an event with free advertising. This was demonstrated through a local magazine providing free online promotions for a community group that lacked funding. This case adds doubt to the argument that new media, specifically Internet use, correlates with decreased social support as a result of weaker and broader community ties (Putnam, 1995). Findings also reflect how social support and community commitment in Peachtree Corners can be developed through new media like Internet-based user-generated media, such as an app with a community calendar. This challenges the idea that new media relates to a broader decrease in community commitment (Wellman et al., 2001) and suggests that there may be a positive relationship between the use of new media, network capital, and community commitment within Peachtree Corners.

These findings are vital to understanding the effects that new media can have on contemporary, Internet-based communities like Peachtree Corners. Technology is constantly evolving and may be of benefit in the formation and facilitation of community relationships. From increasing participation and facilitating communication through pervasive awareness to increasing social support and commitment within a community, new media can be a powerful tool. This city-specific case delves into the relationship between new media and network capital in an innovative and diverse community, which is valuable to the overall study of the effects of rapidly changing technology.

However, because this is a city-specific study, the results of this analysis cannot be extended to all communities around the world – even if it is a diverse city. Peachtree Corners is also a relatively upper-class city with a six-figure average household income, meaning the use of technology and trends described may differ in other lower-income areas. Therefore, future studies should continue to observe areas with differing socio-economic characteristics. Likewise, experiences with and knowledge about digital technologies may also impact the extent to which these new media may benefit communities. As such, future work might benefit from observing differences among communities where digital inequalities are abundant. Technology is continuously evolving and will not stop in the near future. If the results of this study are already different than those of the last decades, the results of future studies will certainly vary. The impacts and influences of new media on communities and community relationships need to be continuously monitored as new methods of using media are developed.

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Investigating Brain Function and Structure Differences During Inhibition By Siming Lui

Abstract

About 75 million people are affected by autism spectrum disorder worldwide and it is estimated that 1 in 100 children are diagnosed with autism spectrum disorder as of 2021. Autism spectrum disorder also occurs four times more frequently in males than females. Autism spectrum disorder is a neurodevelopmental disorder characterized by challenges with social communication, restrictive interests, and repetitive behaviors and usually begins before the age of three. Although scientists are still unsure about the underlying causes of autism, much research has been conducted recently to help us understand more about autism spectrum disorder. It has been shown that children with autism experience difficulty with executive functions. Executive functions regulate control of behavior and thought processes. Differences in executive function may affect one's experience with planning, working memory, attention, problem solving, verbal reasoning, inhibition control, cognitive flexibility, initiation of actions and monitoring of actions. It is important to note that not all individuals with autism have difficulties with executive functions, and some only struggle in a particular cognitive domain. One such domain that is particularly affected in autism spectrum disorder is inhibitory control. Inhibitory control is the ability to suppress automatic urges and behavioral response, and also controls our ability to think before we react. Scientists have used different methods for investigating brain function, including functional magnetic resonance imaging (fMRI), or electroencephalogram (EEG) to study brain function in individuals with autism. These tools can help us identify how executive functions differ between people with and without autism. This review paper will explain how brain function during inhibitory control differs in children with and without autism spectrum disorder and discuss the methods that can be used to detect the differences.

Relevance

With a higher prevalence of autism among the global population today, it is crucial to continue conducting research on ASD and search for a possible cure for ASD. According to studies, ASD may be heritable and the environment may contribute to an increased risk of autism in children (NIEHS). ASD is said to be highly heritable in which a combination of commonly found genetic variations can raise the likelihood of developing autism (Sampson). Children who inherit rare mutations from their unaffected parents (i.e., without ASD) are more likely to have autism (Sampson). While the exact environmental effects related to autism are still unclear, studies show that there are a few factors that lead to higher autism risk. The first one would be prenatal conditions and maternal factors (NIEHS). A problem in a mother's immune system or inflammation during pregnancy may result in higher autism risk for her children as antibodies fight infections in the mother's body and potentially interfere with the children's brain development, leading to autism (NIEHS). Another possible factor is the presence of metals, pesticides, and other contaminants (NIEHS). Research shows that early exposure to toxic and harmful metals such as mercury and lead, or other contaminants, may interfere with their brain

development and potentially lead to autism (NIEHS). In order to find an effective treatment for autism and to understand more about the causes of the disorder, we must devote more resources and funding to research institutes or scientists. By discovering new findings, we may be able to find a treatment for ASD sooner in the future and be able to ensure better life quality.

Introduction

Autism spectrum disorder (ASD) affects approximately one in 100 children worldwide (WHO) with a prevalence of four to five times more in boys than girls (PMC). ASD is a developmental condition that involves challenges with social communication, restricted interests and repetitive behavior; it is a lifelong disorder. A person with ASD may experience struggles in managing time, completing tasks, and regulating self control (American Psychiatric Association). It is believed that the difference of executive functions in autistic individuals lead to their challenges and differences. Executive function is a mental process that allows for planning, focusing attention, remembering instructions and completing multiple tasks successfully (Harvard). One domain of executive function that is particularly impaired in ASD is inhibitory control. It is the ability to control behaviors, emotions and cognitions in order to adapt to the natural and social environment (Musek). The present review paper will focus on the executive function, inhibitory control, and how inhibitory control differs in children with and without autism spectrum disorder.

Diagnosis & Symptoms

To diagnose a child with ASD, the child must show persistent deficits of three areas of social communication. One of these areas is social-emotional reciprocity, which involves the ability to keep a conversation flowing and initiate and respond to social interactions. Another area is nonverbal communication, which captures things like eye contact, body language, and the use of gestures. The third area is difficulty in developing and maintaining relationships because of a variety of factors, including, for example, the struggle to comprehend social cues (CDC). Other than the three areas of social communication and interaction, the child will also have to show at least two of the four types of restrictive, repetitive behaviors. The first behavior is stereotyped or repetitive motor movements. The second behavior is feeling obligated to repeat the same set of actions or routines continuously. Failure to fulfill said routines or tasks would result in extreme distress. The third behavior is very specific interests that are exceptionally intense or focused. The last behavior is hyper- or hypo-reactivity to sensory input and unusual interest in learning about the environment through body senses (CDC).

Autism in young children shows symptoms of being unresponsive to their names, not reciprocating facial expressions or gestures in a social interaction, talking less than other children and doing repetitive movements (Lenroot & Yeung). Autism in older children may present as difficulty with comprehending what others are thinking or feeling, unusual speech, strict daily routine, especially keen interest on a particular subject or activity, trouble making friends and maintaining relationships and trouble in expressing themselves (Lenroot & Yeung).

Brain Structure In ASD

The structural differences shown in the brains of ASD individuals cause functional differences in their brains. Studies show that children with ASD often have abnormal structure and function of the amygdala, an emotional processing center (Šimić et al.). Individuals with ASD often have an enlarged brain volume, though the effects of it remain unclear due to inconsistent results (Abell et al.). Although increased brain volume in early stages is one of the most consistently reported observations, it has not been found in all studies, possibly from differences in diagnosis or inclusion criteria, age, and intelligence of participants. This inconsistency therefore leads to different conclusions on brain structural differences. However, some scientists also found that concentration of gray matter increases in brain structural regions associated with social cognition, communication and repetitive behaviors. Gray matter contains most neuronal cell bodies in our brains and helps process and deliver information to different parts of our body. The increase in gray matter in these brain regions indicates enhanced perceptual functioning in ASD (Motttron et al.).

Tools & Method

To detect autism, tools like functional magnetic resonance imaging (fMRI) and electroencephalogram (EEG) are mostly used to measure brain activity of individuals with or suspected to have ASD. fMRI measures the amount of oxygen being used by a brain region and shows which region is the most active. The more active the region is, the more oxygen-carrying blood is being transported to that brain region. Through fMRI, scientists found in those with ASD a decreased activation of brain region(s) during tasks related to auditory and language processing but an increase during social tasks and comprehending more complex emotions and words (Lenroot and Yeung).

Studies also show abnormal amygdala volume in individuals with ASD (Guo et al.). The amygdala produces responses to facial expressions and detects threats. Research shows that individuals with ASD exhibit decreased functional connectivity among the left and right amygdala and other subcortical brain regions (Guo et al.). Decreased connectivity among these brain regions may result in social impairments (Guo et al.). FMRI is also used to detect sensory abnormalities. In one study, the individuals with autism in the experiment showed significantly less blood oxygenation level dependent (BOLD) response to pleasant and neutral stimuli while demonstrating increased activations in particular brain regions, such as the somatosensory cortex and insula, during unpleasant stimuli (Lenroot & Yeung).

On the other hand, EEG records waves of electrical activity that sweep across the brain's surface measured by electrodes placed on the scalp. The electrodes detect tiny electrical charges that result from the activity of the brain cells. EEG is most often used to evaluate the type of brain disorder by mapping brain function and identifying the exact location of the source of epileptic seizures (John Hopkins). It is also a helpful research tool for scientists to better understand human brain function, including in individuals with ASD.

Inhibition Abilities

Executive functions (EF) regulate, control, and manage our thoughts and actions. EFs also signal to other brain systems to work, stop, or slow down (Bennie). Deficits in executive function affect one's ability with planning, working memory, attention, problem solving, verbal reasoning, inhibition, cognitive flexibility, initiation of actions and monitoring of actions. However, not all diagnosed individuals experience difficulties with EF functions, some only struggle in a particular area (Bennie). One of the main components of EF is inhibition. Inhibitory control is the ability to suppress actions that may interfere with goal-directed behaviors (Diamond). In other words, inhibition regulates our impulse control which suppresses automatic urges and behavior in response and controls our ability to think before we act. Lack of inhibition may lead to emotional outbursts, hand flapping, and stimming. Children with ASD who struggle with inhibitory control may struggle to control their impulses.

To measure one's inhibitory control abilities, go/no-go and stop-signal tasks are often used (Diamond). In these tasks, participants are often asked to perform a quick motor response. An example would be pressing a key on the keyboard as quickly as possible when a target or object, which is regarded as the stimuli, appears on the computer screen (Meule).

Go/No-go Tasks & Stop Signal Task

In go/no-go tasks, it is necessary to ensure that participants are making enough commission errors (i.e., pressing the button when a non-target or distractor is shown on the screen) during in no-go trials. Another type of error is known as the omission error where the participant does not press the button in go trials, known as misses. In go/no-go tasks, the majority of trials are go tasks with just a small number of no-go tasks. The number of errors will be calculated to measure one's inhibitory control abilities (Kaufman et al.).

The second method used to measure inhibitory control abilities is the stop-signal task. Stop-signal tasks are similar to go/no-go tasks. However, the stop signal is initiated after the go stimulus, not presented simultaneously with or instead of the go stimulus. In stop-signal tasks, participants are presented with one crucial stimulus and are asked to respond as fast as possible. The second stimulus, known as the stop signal, appears after the go stimulus. The delay between the go stimuli and the stop signal is known as the stop-signal reaction time (SSRT). The SSRT captures the minimal required time to inhibit an already presented response (Fischer & Jocham).

Effects of Inhibitory Control In Brain

By conducting the go/no task and stop-signal task in groups of individuals with and without autism, scientists are able to map brain regions that are associated with inhibitory control and understand how its function differs from individuals without ASD. One of the most common findings is reduced brain activation in the anterior cingulate cortex (ACC) in individuals with ASD compared to individuals without ASD during the performance of inhibition tasks (Kana et al.). The ACC helps regulate our emotions, pain perception, and cognitive control (Braem et al.).

It is also known to be an important cortical center for incorporating pain with emotional and situational cues. The second finding is that under more demanding inhibition conditions that involve working memory, individuals with ASD exhibit more activation in the premotor areas than individuals without ASD. The premotor cortex is involved in planning and organizing movements and actions (Sira & Mateer). The neurons in the premotor cortex help signal preparation for movement through coordination with other regions of the brain in choosing the appropriate motion to execute (Sira & Mateer). Enhanced activation of the premotor cortex may increase the severity of sensory hyper-responsiveness. It is important to know that both findings are still inconsistent but the level of activation in regions associated with inhibitory controls is certain to affect the function of the region in respect to how active it is.

Conclusion

Brain functions of children with and without ASD differ in various ways and impact the lives of children with ASD. Due to structural and functional differences of the brain in ASD, individuals with ASD often experience social challenges, struggles in regulating behaviors, and difficulty with completing daily tasks. Individuals with ASD who have deficits in inhibitory control in particular also demonstrate difficulties in emotion regulation and impulse control. Studies have shown that there are structural abnormalities in the brain region amygdala among individuals with ASD. Recent work additionally suggests that decreased activation in certain brain regions during tasks related to auditory and language processing as well as decreased connectivity between the right and left amygdala may contribute to social impairments among individuals with ASD. The symptoms of ASD can interfere with daily activities and brain function, making it difficult for individuals with ASD to fit in, thereby causing many to lack a sense of belonging to the community and confidence in themselves. With the increased prevalence of ASD today, we must spread awareness of ASD with people around us and study further into the disorder. By further studying ASD, we can contribute to efforts to find appropriate and effective treatments for ASD, thereby mitigating negative long-term outcomes among children with ASD.

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***Trouble Here, Trouble There: Punk's Origins in the US and the UK* By Sandhya Mathew**

Abstract

The punk subculture came to be in the early 1970's in the US and the UK as a social revolt in response to the conservative politics of the Reagan and Thatcher era. The punk scene juxtaposed widespread feelings of anger and resentment for society with its core values of fierce acceptance and unapologetic pride in diversity. These ideas manifested themselves into aggressive styles of music and fashion that appealed to youth who sought community, with lyrics that openly criticized the government and clothes that unashamedly promoted sexuality and social deviance. Punk is inherently political, and the sentiment of prioritizing people over conservatism continues today in a rising counterculture against an international political climate that parallels that of the 1970's. This paper explores the political context of the culture's development, as well as specific people and groups from which the distinct trends of the punk scene originated and the ideological implications behind them.

Introduction

Punk music emerged roughly in the early 1970s on both sides of the Atlantic - the Sex Pistols pioneering the sound in the UK, and the Ramones popularizing it in the US. The clothing and punk style developed after, with Vivienne Westwood's SEX Boutique introducing leather and spike elements into the scene. But a widespread sentiment of aggression and anger had to come from somewhere - counterculture as a concept has societal implications, not just music and fashion. What conditions could invoke such emotion in the youth of the era? Why did punk feel the need to be so loud? This paper will explore the political foundations of punk culture's development, and how they impacted punk era music and fashion.

Political Implications

Politics and art have always been intertwined. Art and culture stem directly from the conditions and experiences of the people, which are greatly influenced by the laws made to govern them. In the late 1970's and early 1980's came the rise of British Prime Minister Margaret Thatcher and American President Ronald Reagan, whose policies drastically changed the economies of their respective countries.

Margaret Thatcher's ideology had devastating effects for the UK. Her actions against the welfare programs left many without a means to survive, but her union-busting pastime stripped rights and power away from workers, leaving them dangerously unprotected (Hoover). The economic shift towards free-market privatization meant that workers were additionally more at risk for exploitation by private companies, which then dominated the market. General conservatism also included bigotry, with Section 28 criminalizing homosexuality even more than it was already antagonized in the UK. Cultural discriminations like these invoke emotion, and artistic movements soon follow (Martinez).

At this time, welfare programs are also changing in the US. Reagan's New Federalism program in 1981 reinforced traditionalist conservative capitalism, with massive budget cuts and shifts in power in favor of states' rights. With more power and block grants going towards the states, federal welfare programs including food stamps, the AFDC (Aid to Families with Dependent Children) and the Women, Infants and Children program. These, of course, severely impacted the working class, disproportionately hitting women and children.

These conservative ideas are still very present in modern-day Britain and America. Conservatism, economic collapse, and worker suppression are still very relevant issues. The looming presences of Donald Trump and Boris Johnson are not at all unfamiliar, with Trump's Christian-focused nationalism, tax cuts favoring the rich, and stark anti-unionism is eerily familiar to Reagan. One can see the similar parallels in Johnson and Thatcher, both weakening the working class and inciting distrust and division in Northern UK. Reagan and Thatcher undoubtedly set this precedent, but the resulting public outcry clearly marks what side of history these figures are on (Stalcup).

Noise as Rebellion

Anger is a volatile emotion, and by the mid-eighties, it was coursing through the veins of both Britain and America. The Western world was in shambles. The UK was rioting, and the US was in a recession. In a time of chaos, anger, and injustice, comes the voice of the people - a bitter, resentful, and spiteful explosion of art and music. At this point in time, a full generation of young people and the collective working class can be seen up in arms against these governments that were taking their rights, and this translated directly into a loud counterculture. Indeed, rebellion characterized the era, marking it as a turning point in British and American culture.

The Sex Pistols are undoubtedly the first "punk" band. Up until that point, popular music was not considered political. How could it, when it was a product itself? Popular music, by nature, could never be anti-capitalist because it was mass-produced and mass-consumed; there was nothing rebellious about it, and any attempted political statement attached to it would have no weight - in fact, it would be hypocritical. But the Sex Pistols were an emergence of music primarily based on politics and self-expression, not on money or fame. Their debut single, *Anarchy in the UK*, exemplifies these values, with lyrics like "Oh I am an antiChrist/And I am an anarchist" and "Cause I, I want to be, anarchy/Fuck the rat race man" mocking religion and denouncing capitalist mindset in a shocking show of rebellion. Their second single, *God Save the Queen*, goes on to explicitly antagonize the British monarchy, with lyrics like "God save the queen/the fascist regime" and "God save the queen/cause tourists are money/and our figurehead/is not what she seems" openly calling the Queen corrupt and greedy. Loud statements like these drew attention and controversy, but also appealed to the youth who felt mistreated by society and wronged by the power structures in place.

The Ramones mirrored the Sex Pistols in the US, (Ambrosch) releasing songs on growing up and being bored and angry with society. These sentiments drew the collective attention of the younger generations, (Turrini) who saw themselves in the emotions portrayed in punk music.

Songs like “Sheena is a Punk Rocker,” on teenage rebellion and self expression, as well as “Now I Wanna Sniff Some Glue,” on feeling lost as a young person, really appealed to a nihilist generation whose societies were collapsing around them. The Ramones also wrote songs with direct political statements, like “Blitzkrieg Bop” denouncing Nazism. Bands during this time period emerged with similar principles, like all female punk band the Slits.

Although rock music was overwhelmingly male-dominated at the time, punk music’s inherent outlet for anger against systemic oppression all but invited women to express their frustration with the patriarchy. Strong, passionate political beliefs like feminism lent themselves to behavior and fashion, in addition to music. The Slits defined the feminist punk movement within the subculture, while Siouxsie and the Banshees became known as one of the most iconic alternative rock groups ever, while also being female-led. They exemplified the overlap between post-punk/new wave and goth culture. These bands mark the intersectional solidarity found across alternative cultures.

Intersectionality in the Scene

A culture of anger and strong political beliefs inevitably attracted some right-wing “punks” too - people who tried to incite violence and hate, completely disregarding the origin of punk as anti-authoritarian and in opposition of oppressive structures. Neo-nazi skinheads tried to insert themselves into the punk scene, but were ultimately met with resistance. Dylan Clark from the University of Colorado expands on this in *Notes: Music and the Education of Anger*, writing “Over the years, racist skinheads have been no match for the fury of the anti-racists in the subculture. Even at their apex, neo-Nazi punks were marginal and were severely ostracized by other punks...punks all but excommunicated White supremacists from their ranks.” This is for the most part, unsurprising - yes, anger attracts controversy, but in a culture built around riotous, righteous anger, those who uphold and spread injustice are not welcome.

But because marginalized groups were a part of the community, it was important to distinguish allies from bigots for safety’s sake, and so it became commonplace to express ideology somewhere in one’s appearance. Patches were a notable part of punk fashion in this aspect - they conveyed political beliefs on one’s person, with popular symbols including the circle-A to represent anarchy, the Three Arrows representing anti-fascism, and the anti-fascist flag. Lace code was also used to express political and social beliefs. In this way, politics remained the core of everything in the punk scene, even style and appearance.

An incredibly significant view present in the scene was the acceptance and solidarity - if not full overlap - with queer and diverse communities. Queer and POC people were targeted and discriminated against by the British and American governments, and so they very easily fit into the punk scene that was predicated on social deviance and resistance from oppression. The AIDS crisis exemplified this - the queer community struggled without any intervention or help from the government, and the sentiment of anger and injustice found solidarity in punk. Queer and punk cultures were both ostracized. The motive, in addition to conservatism’s general disgust for a

societal “other,” included bigotry - the fact that punk was so heavily associated with queerness made it more of a target.

Sexual deviancy extended beyond queerness - it also referred to the sexual liberation movement that swept the Western World beyond punk. Bondage and fetishwear became a common addition to the punk uniform, with collars, chokers, and harnesses popularized by Vivienne Westwood, owner of the SEX Boutique in London, who styled the Sex Pistols. Punk fashion developed with a distinctive visually aggressive style, featuring spikes, chains, and bright dyed hair. The deviance from social norms, style, and politics was distasteful. Punk was obscene, vulgar, “disgusting,” but that’s what made it so impactful - unapologetic noise.

The Bigger Picture

The goal of all of this was to *change* the system, of course - loud demands and outward rebellion helped to call attention towards societal issues and normalize criticizing the government. As Michel Serres writes in his 1983 intervention in media studies and information theory *The Parasite*, “.. noise gives rise to a new system, an order that is more complex than the simple chain... The town makes noise, but the noise makes the town.” Enough noise will incite change, and the desires and opinions of the people is what truly reflects the success of a nation. The development of such a substantial counterculture puts into perspective the public’s thoughts on the British monarchy and Parliament and the American Congress.

But as we saw already with the literal style of music, “noise” is not just a demand for change within a societal context, but also simply an expression of anger and injustice - that is caused by society - within an art form. The music itself has a unique, loud, angry sound, and the crowds reflected it - punk shows were accompanied with violent moshing and slamdancing. Saidiya Hartman writes in her 2018 *The Anarchy of Colored Girls Assembled in a Riotous Manner* that “The aesthetic inheritance of “jargon and nonsense” was nothing if not a philosophy of freedom...struggle and flight, death and refusal became music or moaning or joyful noise or discordant sound.” While these thinkers are coming from a different field of study, Serres and Hartman illustrate the core sentiments of the punk movement: an outward cry for change and an indulgent scream of anger.

Conclusion

Punk’s complete disregard for authority and direct antagonization of the UK and US governments provoked strong disapproval in the general public. Punk has not truly been recognized by mainstream culture - although most alternative cultures have been popular at one point or another, punk has retained its independence. Its emotion cannot be diluted; punk cannot be conveyed as more gentle or digestible than it is. Punk will most likely never be fully accepted by the general public because it is so inherently political.

In an age of protest, in an age where the very rights of queer, specifically trans people and POC are wrested away from our grasp, it is more important than ever to recognize and point out the flaws within our government system, and promote a country that protects its citizens. The

parallels in politics between now and the 1970s lend themselves to predict a similar counterculture movement developing, and punk's rebellious sentiment remaining ever-relevant. Punk is not just a fashion style, it's not just a music genre, it's a political statement and mindset that says stand up for the rights of the many, and stand against the corruption and greed of the few.

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A Machine Learning Approach to Calculating Injury Severity of NFL Athletes By Vincent Aquino

Abstract

The NFL (National Football League) is one of the largest sports leagues in the world, with thousands of top-level athletes constantly competing and training. However, over the last decade, the total number of injuries has drastically increased despite the increase in healthcare and awareness for injuries. Our research covers the question of how players' biological information (position and body part injury) and outside factors (weather, temperature, type of field, etc.) affect the severity of injuries within the NFL. In our research, we organized a dataset, graphed the data, and created a machine-learning model. Our primary categories for the model development were: body part, surface type, stadium type, temperature, weather, play type, and position group. By using a logistic regression model, we found that out of the given categories for our model, the most important ones increasing the injury severity of our model were: stadium type, temperature, play type, and position. The ones that decreased the injury severity were body part, surface type, and weather. Primarily using a random forest model, we classified the given injuries of a player into 4 main categories (1-day injuries, 7+ day injuries, 28+ day injuries, 42+ day injuries) and created our prediction model. Our end model had a prediction percentage of roughly 57%, compared to the starting percentage of around 23%.

Introduction

In the 21st century, the sport of American football has exploded in popularity, not just within the boundaries of North America, but around the entire globe. Unfortunately, known for being one of the more brutal contact sports, American football has seen a drastic rise in injuries over the last couple of years. For example, from the year 2020 to 2022, the total number of concussions increased by over 40 (From 172 to 213 total concussions). The total number of alternative injuries such as broken ankles, season-ending knee sprains, broken wrists, and strained shoulders has also skyrocketed in the NFL. Not only are the player's game paychecks and health on the line but their ability to function and live lives after retirement is also being jeopardized. These consistent injuries are not just impacting their current lives, but also their future.

While the NFL has implemented hundreds of measures such as rule changes and research further into their players' safety, one possible solution to their injury issues is through the use of artificial intelligence and machine learning models. Currently, the NFL already is implementing artificial intelligence by using trackers and sensors in the equipment of players. In doing so, these trackers can record where NFL players are moving on plays and can be used further in artificial intelligence models. It can allow corporations like the NFL and their partners like AWS (Amazon Web Services) to determine when injuries most likely happen on the field and how to possibly avoid them in the future.

The results and implementation of these rule changes and artificial intelligence have provided mixed results. While the number of a certain type of injuries have gone down, we have also seen a significant rise in other injuries as well. For example, when looking at A.C.L and M.C.L tears, these are some of the worst injuries in the sports world, especially for NFL athletes. Both of these types of tears highly occur during the movement of athletes, often when they are changing direction, jumping, or landing. Not only do these tears sideline players for the rest of their season, but it also requires hundreds of hours of physical therapy and training to get them back to that same elite level. However, the number of these injuries has drastically increased. In the 2021 NFL season, the number of A.C.L tears rose to 71 which is more than double the total just in 2017. Additionally, the number of M.C.L tears has also risen to 129 in 2021, despite having a decline just a few seasons earlier. While artificial intelligence and machine learning implementation in the NFL and other sports still have a long way to go, it is clear that it is capable of preventing injuries and increasing the health of professional athletes. As artificial intelligence and machine learning get more and more advanced, the safer players will be on the football field.

In this machine learning project, we aimed to determine how player biological information (position, type of body part injury) and outside factors (weather, temperature, type of field, etc.) affect the severity of injuries within the NFL. By implementing machine learning and artificial intelligence models, we would be able to classify the specific severity of a player injury and how long they would be sidelined; more specifically answering the research question: How do players' biological information (age, weight, height) and outside factors (weather, temperature, type of field) affect the severity of injuries within the NFL?

Background & Related Works

Over the last couple of years, many research studies have looked further into specific causes of injuries in the NFL. In one specific study from Bryant University's Bryant Digital Repository, they utilized machine learning models including Logistic Regression, Decision Trees, Random Forests, and Gradient Boosted Trees to best determine the injury likelihood of specific players. They concluded that players playing the left guard position and those playing safety and cornerback were the most injury-prone in the NFL. When looking further into this research paper, there were many positives that we relayed over into our own research including utilizing an F1 Score to determine the performance of our models, using different types of machine learning models, and graphing the specific traits of players.

On a broader scale, one research paper from Science Direct looked at younger football players whether they be high school students or young college athletes. By doing so they were able to get a wider range of data on injuries to specific players and what were the largest effects on the whole sport, not just the NFL. In their research, they utilized decision tree machine learning models to determine which body types of players were the most injury prone. They specifically used numerical data such as size, weight, height, running times, and overall statistics of these young athletes to later compare them to each other. Conclusively, they were able to find which type of body type is the most injury prone. This is something we considered heavily in my

research as well; not just looking at situational factors like weather, temperature, stadium type, etc. but also looking at biological factors including body part injuries. In addition, we also implemented numerical data in our models rather than just language data similar to this study.

Furthermore, many other research papers dive further into the specific causes of a variety of body part injuries whether it be lower body injuries, sprains and tears in ligaments, concussions, and much more. However, for our specific research project, we wanted to look further into the actual severity of injuries in players; not just simply stating the most harmful causes, but also how long these players would be sidelined. In doing so, in future projects, we could add to this research to make an application that provides injured players with necessary steps in their rehab process, or altogether avoid specific injuries.

Dataset

In this research project, we utilized an official Kaggle dataset from the NFL. This dataset consisted of 3 different files with primarily numerical and character values. By using a python library called Pandas, we merged the data across all of these three files, resulting in a total of 105 samples of data. Furthermore, this dataset also had seven features: body part, surface type, stadium type, temperature, weather, play type, and position group.

Before creating our model and starting our predictions, we first graphed the distribution of all the main features using a python library called seaborn.

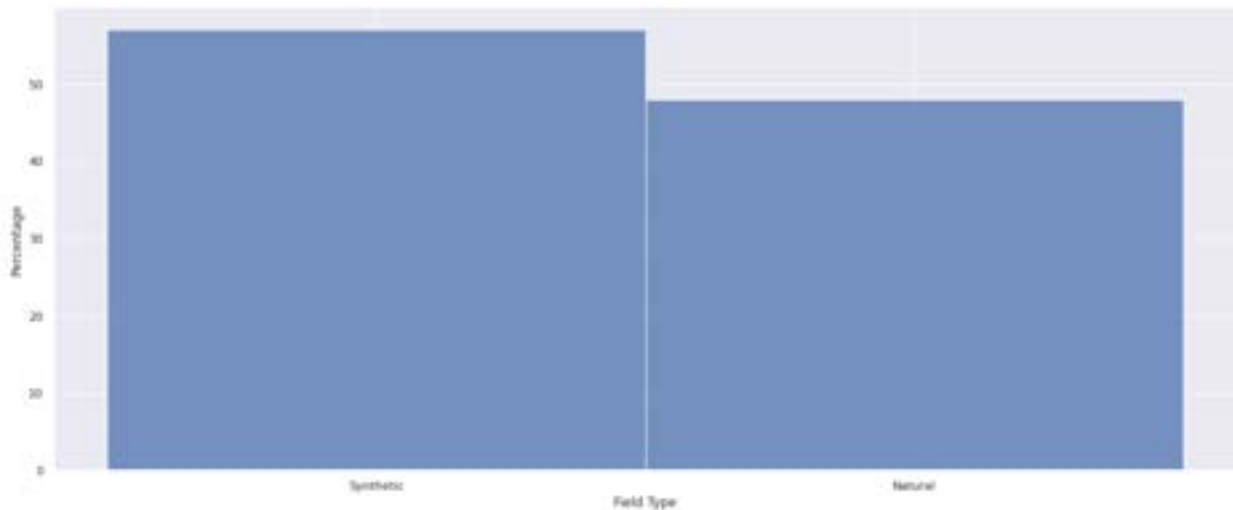


Figure 1: Surface/Field Type Injury Graph. Graph of the percentage of specific field types in the field type column. 54.28% of injuries happened on synthetic fields whilst 45.71% happened on natural fieds.

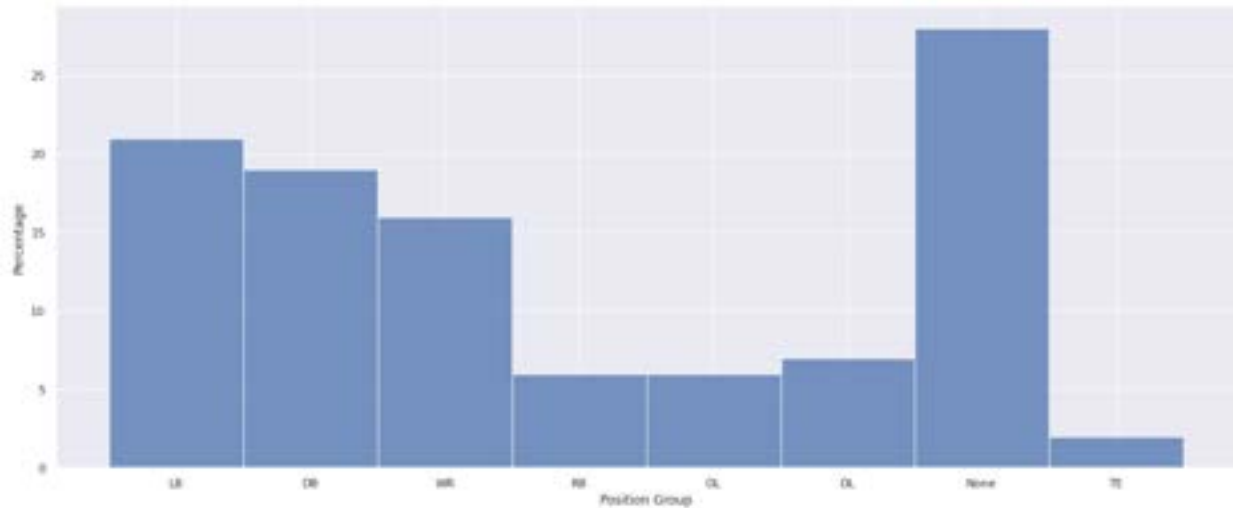


Figure 2: Position Group Injury Graph. Graph of the percentage of the different position groups in the position group column. In this graph we can see that: null values were around 27% of the data, Linebackers (LB) was 20%, Defensive Backs (DB) was 18%, Wide Receivers (WR) were 15%, Defensive Line (DL) were 7%, Running Backs (RB) was 6%, Offensive Line (OL) was 6%, and Tight Ends (TE) were 2%.

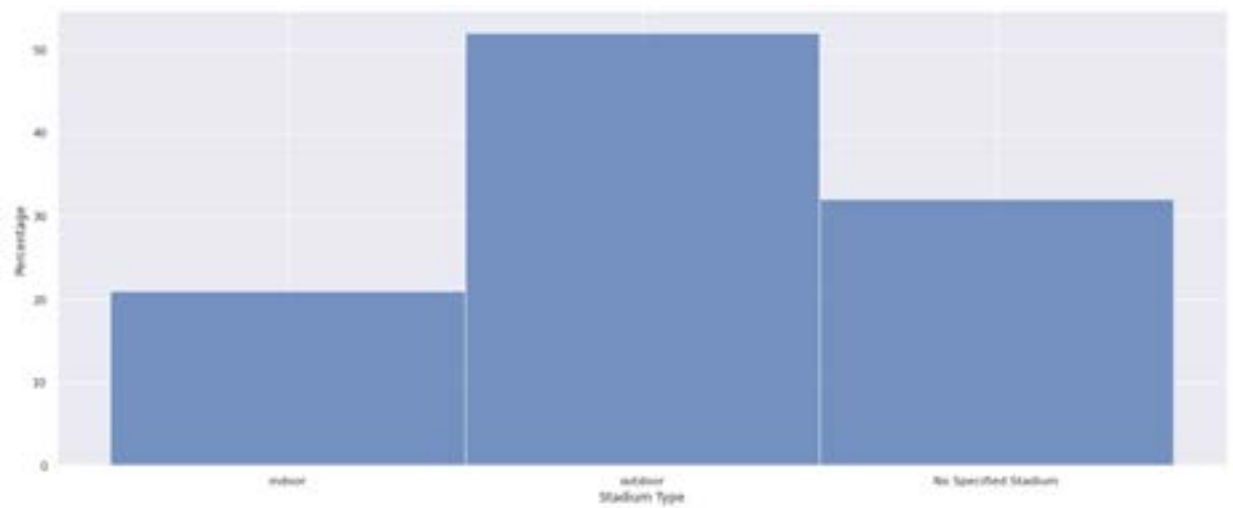


Figure 3: Stadium Type Injury Graph. Graph of the percentage of the different stadium types in the stadium type column. In this graph we can see that: around 50% of the injuries occurred in an outdoor stadium, 20% occurred in an indoor stadium, and 30% of the cases didn't have a specified stadium

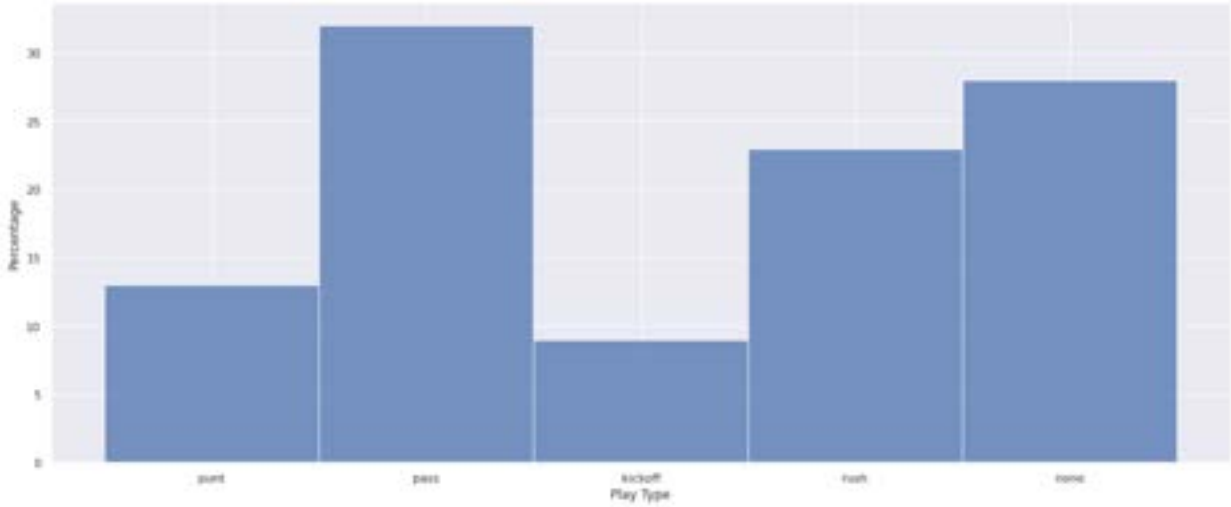


Figure 4: Play Type Injury Graph. Graph of the percentage of the different play types in the play type column. In this graph we can see that: around 30% of the injuries occurred on a pass play, 27% occurred on a null value, 21% happened on a rush attempt, 12% happened on a punt, and 8.5% happened on a kickoff.

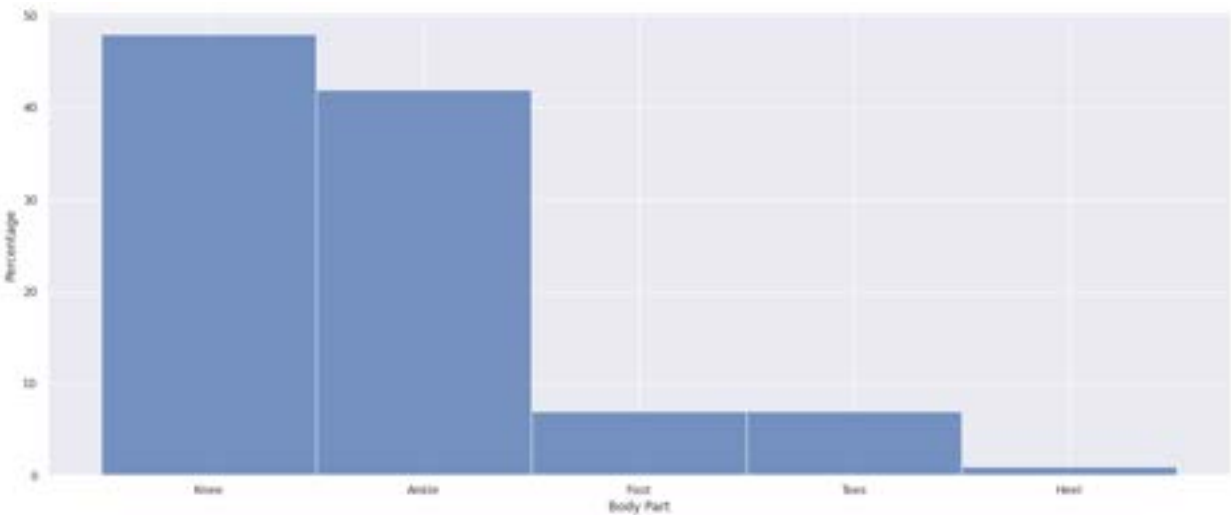


Figure 5: Body part Injury Graph. Graph of the percentage of different body part injuries in the body part column. In this graph we can see that: around 46% of all the injuries were knee injuries, 40% were ankle injuries, 7% of injuries were foot injuries, 7% of injuries were toe injuries, and only 1% of the injuries were heel injuries.

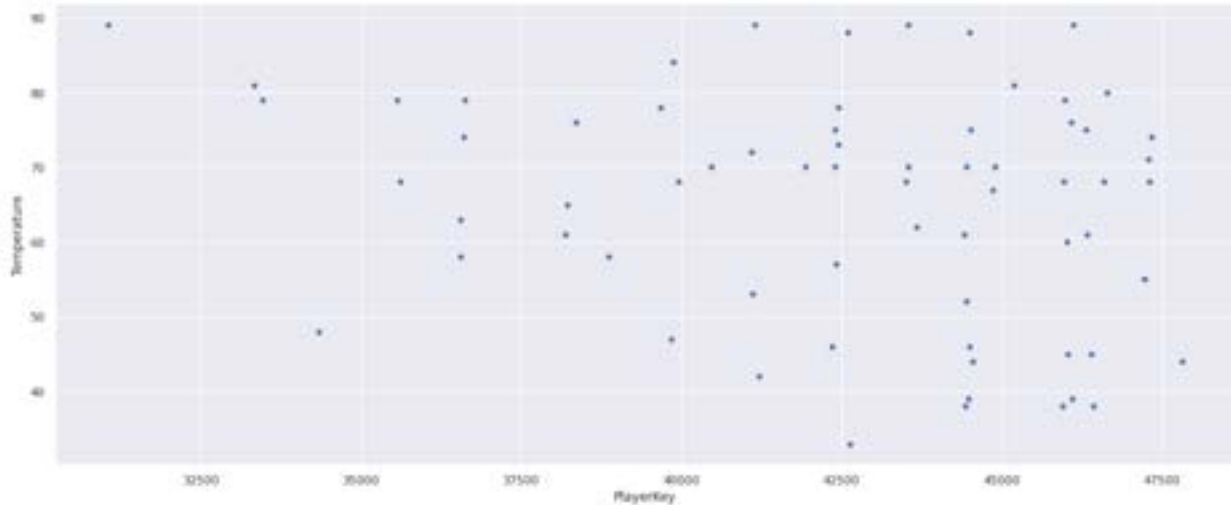


Figure 6: Temperature Injury Graph. Graph of the temperature for certain injuries based on their key. The key is simply just an id for every single injured player. By calculating the mean we get a total of around 65 degrees Fahrenheit.

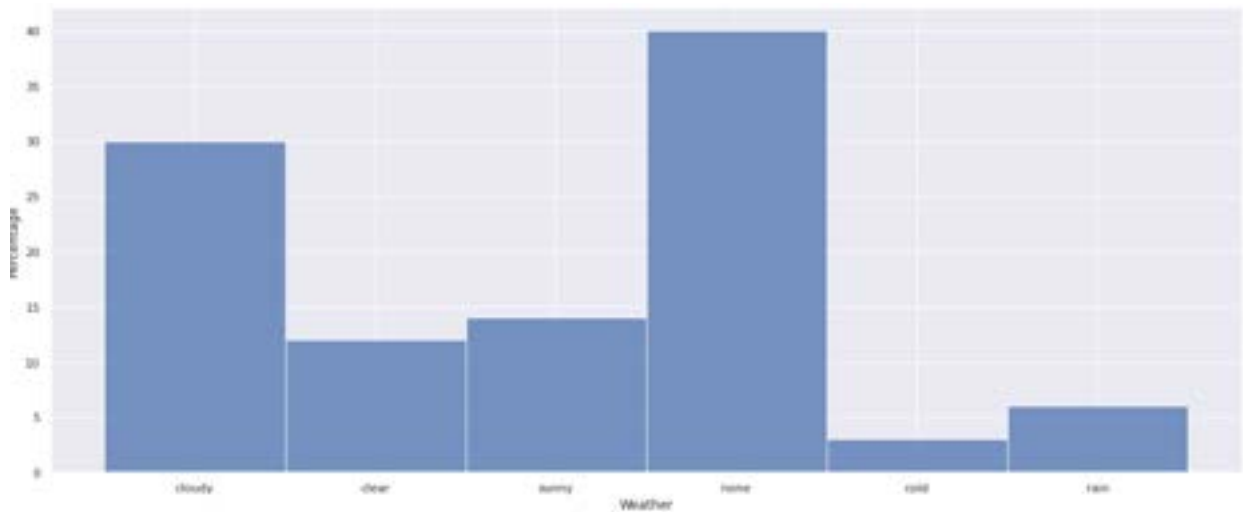


Figure 7: Weather Injury Graph. Graph of the percentage of different weather injuries in the weather column. In this graph we can see that: around 38% of the weather injuries were null, 28.5% of the injuries occurred during cloudy weather, 13% of all the injuries occurred when it was sunny, 11% of all injuries happened when it was clear, 6% of the injuries happened when it was rainy, 3% of the injuries happened when the weather was cold.

Our X-Matrix consisted of seven features: body part, surface type, stadium type, temperature, weather, play type, and position group. To create our X-Matrix we first created a copy of our current data frame and dropped all of the unnecessary columns, leaving just these categories from our data frame.

To create our Y-Vector, we used 4 main categories from our data frame: DM_M1, DM_M7, DM_M28, and DM_M42. These different categories correspond to the number of days

missed from an injury. DM_M1 means that it is a slight injury causing the player to only miss a few days of practice. DM_M7 means that the player is going to miss around 1-2 weeks but won't be sidelined for that long relative to the season. DM_M28 is a slightly more severe injury, meaning that a player would be sidelined for around 4 or more weeks. DM_M42 means that the player has the most severe type of injury missing up to 7 weeks, or around half the NFL season minimum; the number of days and weeks missed could be way larger than this.

Methodology/Models

After graphing all of these features and categories, it was now time to create our X-Matrix and Y-Vectors. X-Matrixes and Y-Vectors are used in artificial intelligence and machine learning research and model development to provide testing and training data for models. This way, models can efficiently and quickly train prediction models that can be used for software, applications, and comprehensive research. An X-Matrix is all of the columns and categories in a data frame that are used to determine the prediction of the model. Think of the X-Matrix as the independent variable of an experiment; the certain values used can drastically change the resulting data and output from the experiment, or in this case, affects the Y-vector. On the other hand, a Y-Vector is the category of the data frame that you want the machine learning model to predict based on the data from the X-Matrix. Think of a Y-Vector as the dependent variable for an experiment; the values of the Y-Vector are determined based on certain variables and data from the independent variable(s), or X-Matrix in this case.

When specifically looking at the current day issue of NFL injuries and attempting to classify the severity of it, there were many different branches we could've possibly ventured off into. Since we knew we were specifically dealing with a classification problem and trying to classify the severity of the injuries, models that dealt with predicting specific values rather than classifying data were impractical for this solution. When looking for a specific type of model, there were two key factors necessary to find to look for: 1) The performance of the model and how accurately it can classify our problem, and 2) The efficiency with which our model was able to calculate and predict our data. Given these two factors, we experimented with two different types of classification models: logistic regression models and random forest classifier models.

Before starting the developmental process of our models, since we were dealing with a classification problem, our models wouldn't be able to function with various types of data such as strings and null values; rather we must convert these values into integers. To solve this issue, we used the `.loc()` and `.str.contains("string")` python functions from the Pandas library. This allowed us to quickly search through columns, find if a value is null or contains a specific string, and quickly change it into a specific integer based on that value. This way we could quickly condense the data and convert it into a type that the model could use. Certain categories of data including Stadium Type, Weather, Play Type, and Position Group, consisted of a high amount of null values in them as seen in the graphs. To deal with this, we first converted the other values in the column into integers, then found the median of the other values, and finally set all of the null

values to the median. This way, we can get more accurate values in our models, rather than just a large amount of null and invalid data. Once doing this, we were now ready to split our dataset.

Before creating our machine learning model, splitting the dataset is necessary. By splitting the dataset at a ratio of 80:20, we were able to make 4 different matrices: X_train, X_test, y_train, and y_test. These 4 matrices consisted of all of the data in our dataset just simply split up. To make our data consistent, we also needed to add a random_state attribute of 42. This number doesn't specifically matter but needs to stay consistent between all models, otherwise, the model would be predicting different numbers every time leading to inconsistent values.

Logistic regression models are commonly used in machine learning applications due to their simplicity and reliability. Logistic regression models deal with probability and create predictions based on estimations and coefficients of given parameters. We initialized and trained the logistic regression model using its default parameters from sklearn and a random_state value of 42. We then evaluated our model using an equation called mean absolute error, which calculates the mean amount of missed values in the list. For the most optimal model, you want the mean_absolute_error() to be as close to 0 as possible. The figure below displays the equation for mean absolute error:

$$\text{MAE} = \frac{\sum_{i=1}^n |y_i - x_i|}{n}$$

MAE = mean absolute error
y_i = prediction
x_i = true value
n = total number of data points

Figure 8: Equation of Mean Absolute Error

A unique aspect of logistic regression models is their ability to easily calculate categorical importance for each feature, which allows us to find the most important variables that affect the predictions of our model. By importing and running another sci-kit-learn function called .coef_, we were able to find the log-odds ratio of each category for our model. A log-odd ratio calculates the odds of a specific prediction occurring for a model, given that all other variables stay the same; meaning that it calculates the effect of each category for a model. This means that a positive odds ratio for a category indicates that a specific event is more likely to happen if that category was used more. On the other hand, a negative odds ratio indicates that this specific category of data causes the event of happening to occur less often.

Random forest models, like logistic regression models, are machine learning models that are often used in artificial intelligence software, research, and applications. Random forest models specifically utilize groups of decision trees, another type of machine learning algorithm, to come to a single classification and prediction. In order to understand random forest models, we first needed to understand decision trees.

We can think of a decision tree as a tree itself. First, the starting data given is called the root node. Then, given certain parameters and algorithmic decisions, the decision tree would further split up this large dataset provided into smaller decision nodes. These decision nodes can be further split into more decision nodes or leaf nodes. A leaf node/terminal node is an even smaller node of data, however, unlike decision nodes, cannot be further split up. This means that this is the end of the split for the data. These leaf nodes each hold the predicted classification for the decision tree and once all of the decision nodes are split into leaf nodes, the prediction is finally complete. Below is a diagram of a sample decision tree:

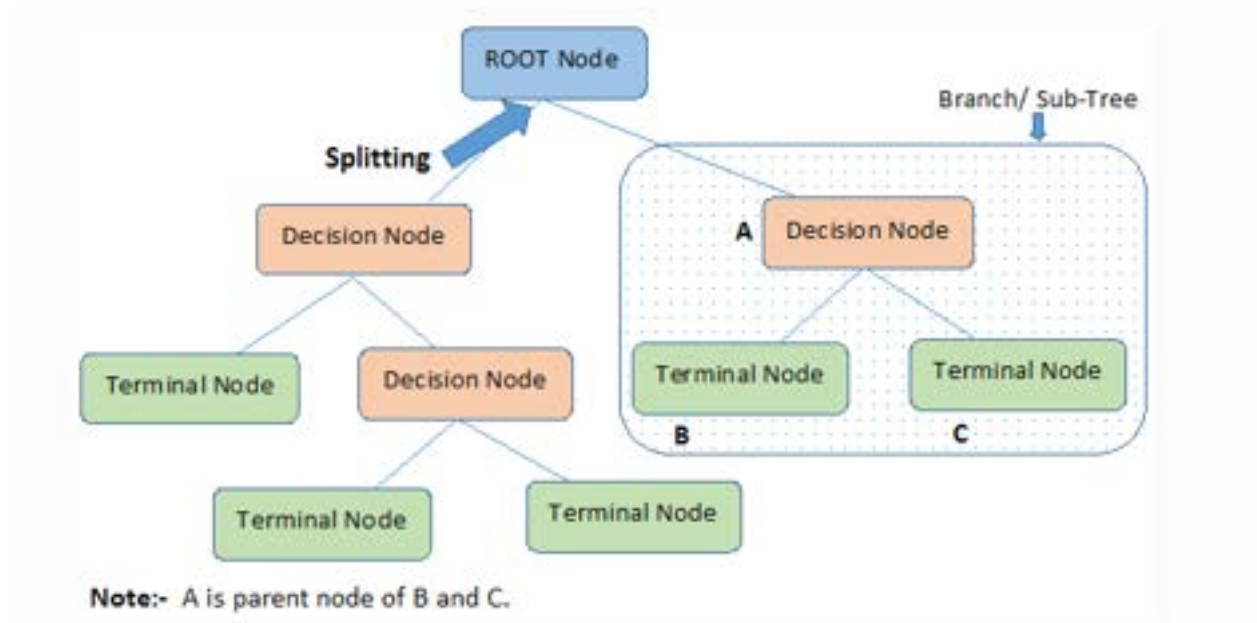


Figure 10: Diagram of a sample decision tree.

After calculating all of the predictions for different decision tree models, the random forest model finds the most optimal decision tree with the highest prediction and uses its data as its prediction. While random forest models have longer run times and can have biased variables, there are still many positives: a large amount of decision trees means that random forest models will have the highest possible accuracy for a model, random forest models can automatically balance datasets when certain classes are unbalanced, and this type of model can easily deal with classification problems. Since we are dealing with a classification problem and have a few unbalanced categories, we would be using random forest models as our primary model for this project.

We first initialized and trained the random forest model using its default parameters from sklearn and a `random_state` value of 42. We also used a `max_depth` of 3. We then evaluated our

model using an equation called mean absolute error, which calculates the mean amount of missed values in the list. We again used the `mean_absolute_error` equation to calculate the mean amount of missed values in the prediction list.

Hyperparameter tuning is a type of machine learning optimization that finds the best set of optimal hyperparameter values for a learning algorithm by applying it to a model. A certain combination of hyperparameters maximizes the performance of the model and minimizes the losses in the function to increase its accuracy of it. In our random forest model, we will be tuning four different hyperparameters: `max_depth`, `n_estimators`, `min_samples_split`, and `min_samples_leaf`.

The `max_depth` of a random forest model is the longest possible branch that can be created for a model. For example, if the `max_depth` of a random forest model was four, the maximum amount of splits made in the decision trees could only go up to four.

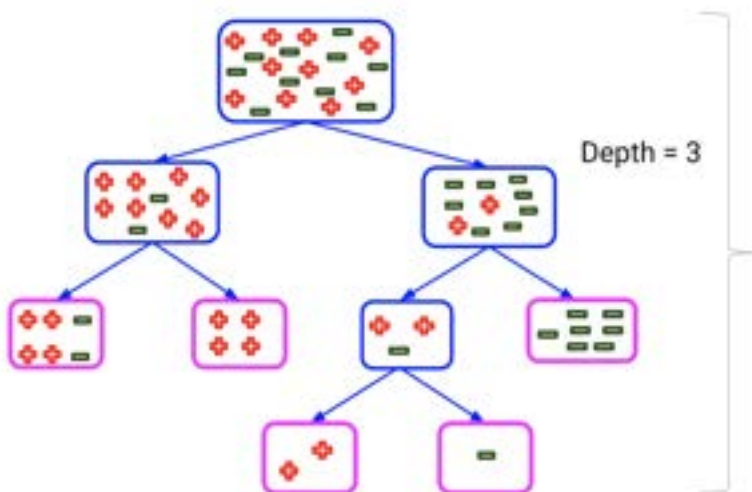


Figure 11: Diagram of `max_depth` hyperparameter in a decision tree. In this example, since the `max_depth` is three, the maximum amount of splits possible is 3.

In order to figure out the possible `max_depth`s for our model, we needed to find the minimum and maximum range of values for it to increase performance. We found this range by running a for loop and appending all of the `max_depth` values into a list. We can notice that after around the `max_depth` of 15, the accuracy scores start to plateau and no longer increase. This means that when tuning the `max_depth` feature, we only have to look between the values of 1 to 15. This will drastically decrease the runtime for our program and allow the random forest model to perform more efficiently and quickly.

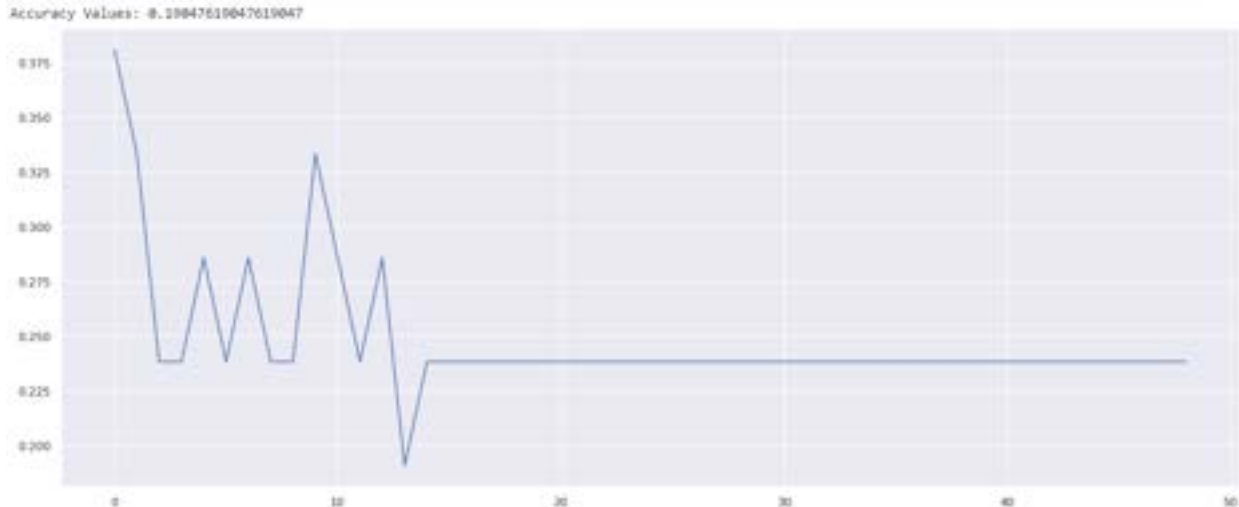


Figure 12: Graph of the accuracy scores of the random forest model relative to the given max_depth hyperparameter.

After figuring out the range of values provided, it was now time to optimize all of the listed hyperparameters. For all of the hyperparameters besides max_depth, we gave a range of 1 to 50 since when testing out different models, none of these hyperparameters would go over or under these numbers. Once looping through all of these hyperparameters, we saved the optimal max_depth, n_estimators, min_samples_split, and min_samples_leaf into a list. We then saved the list data into a dataframe and graphed the optimal accuracy for a given depth.

Results and Discussion

After running our logistic regression model and using the mean absolute error equation, we got a mean absolute error of 1.428, which overall means this model has lots of room for improvement.

Furthermore, we also obtained the categorical importance of our different categories, based on the .coef_ function and the log-odd ratio of the category. Below is a figure of all of the categories and their log-odd ratios.

Category	Log-Odd Ratio
Body Part	-2.931
Surface Type	-2.359
Stadium Type	2.141
Temperature	1.163
Weather	-3.604
Play Type	1.967
Position	4.864

Figure: 9: Table of log-odd ratios depending on the given category for the model. Green highlighted values represent positive values that cause injury rates to go up in our model. Red highlighted values represent negative values that cause injury rates in our model to go down.

As seen in the figure above, we can see that relative to our model, many different categories affect the predictions. The category that caused the largest increase in injury severity was “position” at around 4.864. Considering the fact that the NFL is very physically diverse depending on the position you play, this data makes sense. Other categories that cause the severity of injuries to increase in our model are stadium type, temperature, and play type. A few categories also cause the injury severity predicted in our model to actually go down. These categories are weather, surface type, and body part.

Without tuning our random first model, we again used the `mean_absolute_error()` function to calculate the mean amount of missed values in the prediction list. In our case, the mean absolute error was around 1.571, meaning our model can drastically improve.

Once tuning the `max_depth`, `n_estimators`, `min_samples_split`, and `min_samples_leaf` of the random forest model, we saw that the most optimal random forest model occurred during a max depth of 4. The most optimal `n_estimators` was 9, the most optimal `min_samples_split` was 6, and the optimal `min_samples_leaf` was 3. When looking back on our original dataset, we had 4 different possible classification outcomes, meaning that by random draw, you would always have around a 25% chance to get the correct number. Seeing as our model was able to get those odds up to 57.14%, this is a drastic improvement. Below is a figure displaying all of the accuracy results for our the different `max_depth` features:

Depth	Starting Accuracy	Optimized Accuracy	Accuracy Increase
1	0.380952	0.523810	0.142857
2	0.333333	0.476190	0.142857
3	0.238095	0.476190	0.238095
4	0.238095	0.571429	0.333333
5	0.285714	0.428571	0.142857
6	0.238095	0.476190	0.238095
7	0.285714	0.428571	0.142857
8	0.238095	0.523810	0.285714
9	0.238095	0.428571	0.190476
10	0.333333	0.428571	0.095238
11	0.285714	0.428571	0.142857
12	0.238095	0.428571	0.190476
13	0.285714	0.476190	0.190476
14	0.190476	0.428571	0.238095
15	0.238095	0.476190	0.238095

Figure 13: Table of all of the given max_depth hyperparameters and their given starting accuracy, optimized accuracy, and total accuracy increase.

In machine learning, not only can accuracy be used to determine how well your model performed, but, there are also other metrics such as precision and recall. Precision can be considered a metric that measures the accuracy of positive predictions in a classification model. In our case, precision can be used for a specific injury severity value and help us find out where our model is losing some of its accuracies. Precision can also be defined by the equation:

$$\text{Precision} = \frac{\text{True Positive}}{(\text{True Positive} + \text{False Positive})}$$

Recall, on the other hand, can be considered a model metric that measures the completeness of positive predictions and looks on a broader scale. In our case, we can see how for all of the players with a specific injury severity, how many we correctly identified. Recall can also be defined by the equation:

$$\text{Recall} = \frac{\text{True Positive}}{(\text{True Positive} + \text{False Negative})}$$

In addition to precision and recall, there is also a model metric called an F1 score. An F1 score is able to combine both precision and recall together to determine how well a model performed. The closer an F1 score is to 1, the better it is. The closer it is to 0, the worse it is. The equation for an F1 score can be defined by the equation:

$$F_1 = 2 \times \frac{\text{precision} \times \text{recall}}{\text{precision} + \text{recall}}$$

Codewise, we simply use python functions to take in our predicted and test value lists to calculate all of these model metrics.

Classification Value	Precision	Recall	F1 Score
1	0.2	0.5	0.2857
2	0.6153	0.89	0.727
3	0	0	0
4	1	0.3	0.5

Figure 14: Table of the precision, recall, and F1 Score metrics for our random forest model.

The figure above displays all of the precision, recall, and f1 scores when classifying the 4 different outcomes for our model. For the injury severity of 1, it had a below-average F1 score of 0.28. While the precision and recall are not optimal, the precision needs to be increased. For the injury severity of 2, it had an above-average F1 score of 0.72. This metric is optimal and means that the injury severity of 2 is being predicted at a high and accurate rate. For the injury severity of 3, it had a below-average F1 score of 0. Since the precision and recall are also 0, this means that currently, our model isn't predicting a classification value of 3. This is likely due to our dataset and the low amount of 3 values in it. For the injury severity of 4, it had an average F1 score of 0.5. Currently, the precision is performing at the most accurate rate being 1. However, the recall is slightly below average at 0.3. Overall, we can see that in our model, we need to slightly adjust to stop unnecessarily predicting 4s and 1s and attempt to predict 3s more often.

Conclusion

Overall, in this NFL Injury notebook, the objective was to find how player information (position, type of body part injury) and other factors (weather, temperature, type of field, stadium type, play type) affect the severity of injuries within the NFL. More specifically, we were looking into how players' biological information (age, weight, height) and outside factors (weather, temperature, type of field) affect the severity of injuries within the NFL. By utilizing a random forest model and tuning the model, our model was able to have a 57% accuracy rate which is great considering the small size of our dataset. However, unfortunately, our current model was unable to predict a category of 3, in part due to its smaller sample size in the dataset

compared to the other listed values. Later on, I hope to add to this research by possibly utilizing a larger and more diverse dataset with more categories and samples. This way, we would eventually be able to increase our accuracy to something significantly higher. In the near future, I also hope to incorporate this model and create a working application that can be used to predict football and NFL player injury severity rates. In doing so, it would be able to provide these players with the necessary data and information that can prevent further serious, life-altering injuries in the future.

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The Influence of Dietary Choices, Lifestyle, and Nutritional Supplements on Tic Disorders

By Mengnan Sun

Abstract

It is shown that children with tic disorders are intolerant to certain foods, which can trigger or exacerbate their symptoms. Adopting a healthy lifestyle has also been suspected to have a correlation with symptom alleviation. Nutritional supplements such as magnesium, vitamin B, vitamin C, D3+K2, probiotics, and omega-3 fatty acids may play a significant role in alleviating patients' tics as well.

This study involved 62 children with tic disorders, examining the exact influence of the factors above, if any, on alleviating their symptoms. The results revealed that by avoiding trigger foods, practicing good lifestyle habits, and incorporating personalized nutritional supplements, 92% of patients experienced a 60% reduction in tic symptoms within one month, 73% achieved an 80% reduction within three months, and 56% became completely tic-free within the same timeframe. Although symptoms may reoccur during periods of illness, stress, or after consuming trigger foods, the combination of these three approaches can lead to symptom reduction within several weeks. This alternative therapy presents a promising method for managing tic disorders.

Introduction

Tic disorder is a wide-covering neurological condition that includes Tourette Syndrome (TS), persistent (or chronic) phonic tic disorder, and provisional (or transient) tic disorder. Tics are sudden, uncontrollable motor movements or vocalizations that individuals, especially children, may repetitively perform. While some tics are provisional and may fade without intervention, others can become frequent and severe, leading to difficulties at school or in social situations. Tic disorders are diverse and currently lack a cure. Common coexisting conditions include attention-deficit/hyperactivity disorder (ADHD) and obsessive-compulsive disorder (OCD).

The primary goal of current treatments for tic disorders is symptom reduction. Neuroleptics, also known as antipsychotics, are the main medications prescribed for tic disorders. They function by modulating brain chemicals to help regulate body movements. However, these medications, such as haloperidol, pimozide, and aripiprazole, can result in various side effects, including weight gain, drug-induced movement disorders, elevated prolactin levels, sedation, and effects on heart rate, blood pressure, and electrocardiogram (ECG).^[1] Discontinuing medication may exacerbate tics, necessitating an increased dosage.

Researchers have explored alternative treatments for tic disorders, with Comprehensive Behavioural Intervention for Tics being the primary approach, particularly for TS.^[2] However, it can be challenging for young children, especially those under six years old. Traditional Chinese medicine has shown effectiveness for some patients, although its safety and efficacy remain uncertain.^[3-4] Deep brain stimulation is considered promising for severe cases unresponsive to other treatments, but it carries potential adverse effects.^[5]

In recent years, natural treatments for tic disorders, in which no medication is involved, have gained attention. Identifying and avoiding triggers, whether environmental or dietary, is crucial to symptom management. Additionally, the use of nutritional supplements concurrently aims to bolster the immune system.^[6]

Literature Review

The impact of diet to tic disorders

Many researchers have studied the impact of diet on symptoms associated with neurological disorders. Amanda K. Ludlow et al. highlighted findings indicating that specific allergens in food may worsen tic-related symptoms, as reported by parents of children with TS.^[7] For instance, increased tics have been linked to the intake of caffeine and refined sugar. Oligoantigenic and sugar-free diets have also been shown to significantly reduce tic occurrences.

A study on the efficacy of a gluten-free diet in TS also showed that maintaining a gluten-free diet for one year resulted in a significant reduction in tics and OCD symptoms in both children and adults.^[8]

Another study on the Long-Term Effects of an Oligoantigenic Diet in Children with ADHD on Core Symptomatology demonstrated that individually-tailored nutritional adjustments substantially improved ADHD symptoms in the long term.^[9] This indicates that an oligoantigenic diet, coupled with personalized nutritional guidance, could serve as an additional treatment option for children with ADHD.

Irena Buka et al. examined the association between food additives, essential nutrients, and neurodevelopmental behavioral disorders in children.^[10] Findings suggested that certain food additives, particularly preservatives and artificial colors, along with inadequate intake of essential nutrients, are linked to hyperactive behaviors and poor attention in some children.

Klaus W. Lange et al. presented preliminary evidence suggesting that minerals may have beneficial effects on ADHD symptomatology, while probiotics could offer novel strategies for prevention or treatment.^[11] Adherence to "healthy" diets has been inversely associated with ADHD symptoms. Children with ADHD who respond to the few-food diet (or oligoantigenic diet) exhibit substantial improvements in behavior and cognitive functioning.

The impact of LifeStyle and Environment to tic disorders

A past study investigated environmental influences on tic expression in children by administering a questionnaire to patients over the age of 5, assessing various environmental factors and daily activities potentially affecting tic occurrence.^[12] Results showed that tics worsened during stressful situations, school-related activities, video gaming, and television viewing. Conversely, many children reported reduced tic symptoms during engagement in artistic or creative activities, as well as sports and outdoor play. Another study explored the specific effects of movie and video game elements on tic exacerbation in children.^[13] It is reported that the plot of the movies (e.g., conflicts between characters, dramatic climaxes) correlates with tic patterns and increases the rate of the tics, strongly suggesting that tics are orchestrated by the movies. A particular exacerbation in tics occurs when the patients expect a certain outcome, especially an award, in the movies or video games.

As reported by patients themselves on the Internet, a healthy lifestyle and a clean and tidy environment are suspected to correlate with tic alleviation. Adopting a healthy lifestyle involves reducing screen time (including computer and cell phone use, TV watching, and video gaming), engaging in outdoor activities for at least an hour per day, fostering a positive family atmosphere, and minimizing family quarrels, especially those in which children are directly involved. Creating a conducive environment entails maintaining a clean room, as dust and mold have been identified as triggers for some tic disorders, and using unscented detergent, among other measures.

The impact of Nutrition Supplements to tic disorders

A study by Smith, B. L. et al. investigated patterns of nutritional supplement use in children with TS.^[14] The most commonly used supplements among children with TS included probiotics, omega-3, multi-vitamins, and magnesium. 75% of supplement users in the TS group reported improvements, particularly in motor and vocal tics, sleep quality, and anxiety reduction.

A separate study examined the clinical relationship between tic disorders and vitamin D levels in children.^[15] The analysis revealed lower vitamin D levels in children with TS compared to healthy children.

Supplementation with L-theanine is demonstrated to possibly aid in treating tic disorders associated with anxiety symptoms, and magnesium and vitamin B6 resulted in a significant decrease in the Yale Global Tic Severity Scale score for patients upon taking, with no observed side effects.^[16-17]

Method

Data was gathered from an online community dedicated to chronic tic disorders and TS in China. A survey was posted in the online community, covering topics such as patient age, gender, symptoms, dietary restrictions, and types of dietary supplements consumed. A total of 62 parents contributed information about their children with tic disorders, aged between 4 and 15 years old, comprising 45 boys and 17 girls.

Tics exhibited by these children encompassed motor tics like eyes blinking, shoulder shrugging, or arm jerking, as well as vocal expressions such as sniffing, snorting, and throat clearing. Approximately 65% of the children were reported to have symptoms of ADHD, while 32% exhibited signs of OCD.

As per parental reports, the most commonly eliminated foods included chocolate, sugar, dairy products (such as milk, yogurt, and cheese), junk food (items with various additives like preservatives and colorants), eggs, gluten, vegetable oil, and fruits high in fructose content such as apples, cherries, and watermelon.

Figure 1 illustrates the rate of food items eliminated from the diets of children with tic disorders.

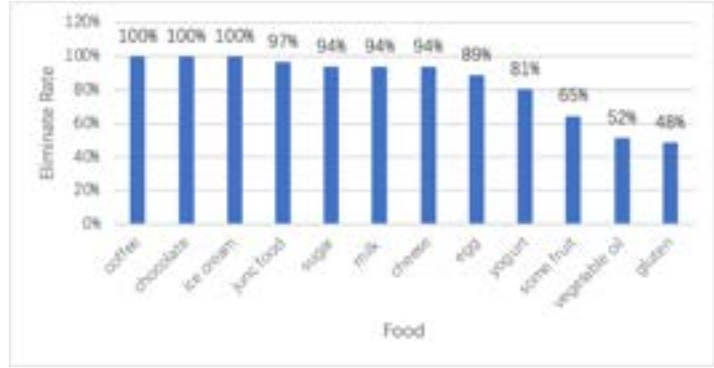


Fig. 1 The rate of food items eliminated from the diets of children with tic disorders

All the children incorporated nutritional supplements into their daily routines. The most commonly used supplements included magnesium, vitamin C, vitamin A, NAC, vitamin B complex, vitamin D and K2, zinc, fish oil, selenium, and probiotics. Figure 2 illustrates the rate of addition of these nutritional supplements among the children.

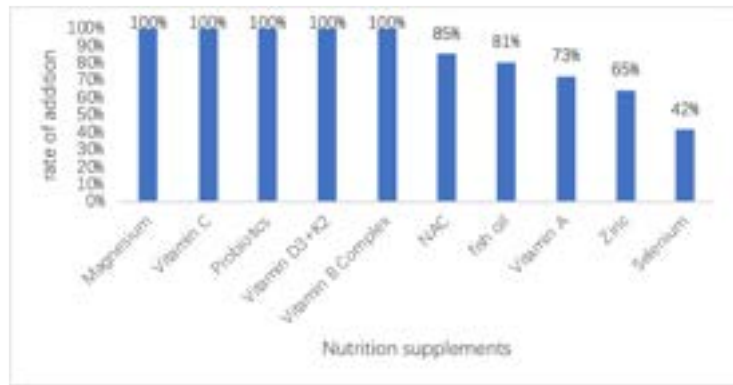


Fig. 2 The rate of addition of nutritional supplements

All the parents of the children recognised the significance of lifestyle and environment in managing tic disorders. They regulated their children's screen time to less than half an hour per day and avoided imposing undue pressure on them. Additionally, they conscientiously considered all aspects of their children's lives that could potentially contribute to tic disorders.

Results

Based on the gathered information, all children experienced alleviation of their symptoms, although the duration required to alleviate symptoms varied among individuals. The time for achieving a 60%, 80%, and 100% reduction in tic disorder symptoms is detailed in Table 1 and depicted in Figure 3.

Table 1 Time to reduce tic disorder symptoms

Percentage of patients	Percentage of symptoms reduced		
	60% of symptoms	80% of symptoms	100% of symptoms
Time			
< a week	40%	10%	5%
1-2 weeks	35%	16%	10%
2-4 weeks	16%	29%	23%
1-3 month	6%	18%	19%

3-6 month	2%	15%	18%
> a year	0%	10%	16%
never	0%	3%	10%

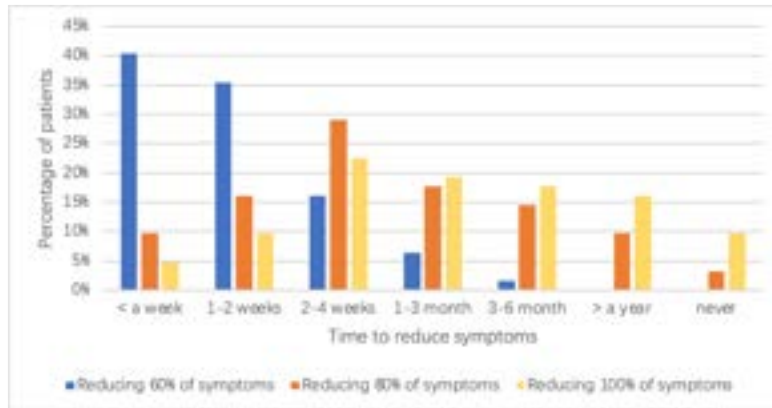


Fig. 3 Time to reduce 60%, 80%, and 100% of tic disorder symptoms

From Figure 3, it's evident that 92% of patients achieved a 60% reduction in their tic symptoms within a month, while 73% experienced an 80% reduction within three months. 56% of the children became completely tic-free within three months.

Despite the initial improvement resulting from dietary changes and nutritional supplementation, nearly all children face the challenge of tic recurrence intermittently. Common triggers for tic recurrence include prolonged use of electronic devices, consumption of intolerant foods, stress, criticism, and other illnesses such as colds or infections. However, by adjusting their diet and continuing nutritional supplementation, tic recurrence typically improves within several weeks.

Conclusion and Discussion

Through dietary adjustments to avoid triggers, lifestyle modifications, and the incorporation of nutritional supplements, nearly all children with tic disorders can alleviate the majority of their symptoms or minimize them to barely noticeable levels. This improvement is crucial for enhancing their daily functioning, social interactions, and self-esteem. While tic recurrence remains a possibility, this alternative therapy shows promise for children with tic disorders. However, the absence of information regarding potential side effects underscores the need for further research in this area.

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Optimizing Study Strategies to Support Neurodivergent Students: A Literature Review By Joanne Roh and Naomi Scherer

Abstract

Students with neurodivergence have a tendency to struggle with academics and independent work. For example, children with attention deficit hyperactivity disorder (ADHD) have been found to score lower on achievement tests (Frazier et al., 2007), while autism spectrum disorder (ASD) is associated with a lack of motivation in academic tasks (Koegel, Singh, & Koegel, 2010). This long-term difficulty with the academic environment has never been sufficiently addressed and accommodations are lacking. In this paper, I will analyze which strategies most effectively support neurodivergent students' (specifically, those with ADHD and ASD) independent work abilities. The three techniques that will be reviewed are the Pomodoro technique, parallel working aka body doubling, and mindfulness. The Pomodoro technique is a method developed to improve time management by doing work in manageable intervals separated by short breaks (pioneered in the 1990s by Francesco Cirillo). Body doubling is a method of working in which two individuals work on the same task side by side (based on the discovery of mirror neurons by Di Pellegrino et al., 1992). Mindfulness is the practice of reflecting on oneself and can be practiced before work to improve productivity (popularized in the Western world by practitioners such as Deepak Chopra and Jon Kabat-Zinn). By reviewing and synthesizing existing research from the fields of psychology and neurobiology, this paper will analyze the strengths and weaknesses of these existing strategies to inform the best learning methodology for neurodivergent students. In addition, the gender- and sex-based differences in symptoms and struggles of people with ADHD or ASD may affect the success of each of these methods. This research will support neurodivergent students in their academic endeavors by determining how and why these methods work for them.

Introduction

Neurodivergence presents unique struggles that affect certain aspects of life such as academics. This paper will focus on Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD). Both ASD and ADHD are neurodivergent disorders, which means that their hypothesized causes are structural differences in the brain. ASD is associated with abnormalities in brain growth, cortical connection, and neuronal patterning (Eberhart and Pardo, 2007) while ADHD is associated with abnormalities in the shape of the prefrontal cortex, caudate nucleus, cerebellar vermis, and corpus striatum (Tripp and Wickens, 2009). Additionally, dopamine and norepinephrine have very often been implicated in the pathophysiology of patients with ADHD.

The symptoms of ASD and ADHD vary slightly between males and females and there are differences in how their ASD and ADHD are externally perceived. For example, males with ADHD often display more symptoms related to hyperactivity while females with ADHD often display symptoms related to inattentiveness (Bölte et al., 2023). For ASD males typically

struggle more with separating from their routines and repetitive behaviors while females typically struggle with communication (Bölte et al., 2023).

These differences manifest in a number of symptoms that can interfere with completing day-to-day tasks such as academic work. ASD and ADHD often interfere with abilities that are important in the academic setting such as focusing, self-regulation, executive functioning, self-control, etc (Goodall et al., 2022). Symptoms of ASD that can interfere with academic settings include difficulties with organization, motivation, concentration, social skills, and planning (DSM-5). Similarly, students with ADHD have been found to struggle with motivation, impulse control, and concentration along with shortened attention spans, hyperactivity, and forgetfulness (DSM-5).

Many of the symptoms of ASD and ADHD result in consequences including poor grades, poor reading and math standardized test scores, increased grade retention, increased rates of detention and expulsion, and, ultimately, relatively low rates of high school graduation and postsecondary education (Feldman and Loe, 2007). Students with ASD and ADHD experience distinct struggles and there are a few solutions that can assist with alleviating those challenges. Some solutions that could work to help these students include study methodologies like the Pomodoro technique, Body Doubling, and practicing mindfulness. The Pomodoro technique is a time management technique in which the student would focus on one task for a manageable amount of time and then take a quick break before starting another period of work time. Body Doubling is a technique where two people work side by side at the same time so that the partners keep each other accountable and motivated. Mindfulness is a form of meditation that involves breathing exercises, yoga, and focusing on one's surroundings in order to make one more in tune with their body and mind. There are a number of unique struggles faced by neurodivergent students but techniques such as those mentioned above could provide some help, and further research can be done. By reviewing these techniques we can find the strengths and weaknesses of each to optimally assist these students.

1. The Pomodoro Technique

1.1. How does it work?

In the 1990s Francesco Cirillo developed a technique to help himself manage his work, named the Pomodoro technique after the tomato-shaped kitchen timer that was an important tool for the method. For Cirillo's technique, he set a timer to 25 minutes and focused on completing a single item for that allotted time, then took a break for 5 minutes before setting another 25 minutes of focused work time (Mandal, 2020). The method that Cirillo invented is still in use today and works as a tool to help students with their school work. Working on only one task for a specific amount of time gives the student a clear idea of what needs to be done and lowers the chances of procrastination. Procrastination can often be caused by a feeling of not knowing how to approach the task or feeling as if the task that needs to be completed is too daunting (Miyake and Kane, 2022). The 25 minute increments followed by the 5 minute break allows for sustained

and focused work. Research has shown that brief mental breaks help one maintain focus on a task (Ariga and Lleras, 2011). The structure of the Pomodoro technique encourages sustained motivation to work. Both ASD and ADHD make it difficult to focus on a topic that is not of interest for extended periods of time (DSM-5) so the shorter increments of work time are likely to have a positive effect on productivity

1.2. Why does this method work with people with neurodivergence?

The Pomodoro technique was not specifically designed with neurodivergent people in mind but targets areas that are struggles for neurodivergent people. The Pomodoro technique emphasizes time management, focus, and motivation, which are areas of struggle found in both ASD and ADHD. Time management is a big challenge for people with ADHD due to their warped perception of time (Weisenberg et al., 2021) and the Pomodoro technique combats this with the constant reminder of how much time they have to work. The physical timer is always there to remind the student of how much time is left and how much has elapsed.

Evidence suggests that there is a connection between ADHD and lowered motivation and reward dysfunction (Haenlein and Caul, 1987). Procrastination is heavily tied to motivation and many of the reasons why one would struggle with motivation are also reasons why one would struggle with procrastination (Miyake and Kane, 2022). According to Piers Steel's temporal motivation theory the four factors that determine motivation (and therefore, procrastination as well) are one's confidence in their ability to complete the task at hand, the value one sees in completing the task, one's impulsiveness, and one's perception of the imminence of the deadline (Steel, 2011). There is a connection between ADHD and increased impulsivity and flawed time perception (DSM-5) (Weisenberg et al., 2021). But on the other hand, there is little connection between ADHD and one's confidence in their ability to complete a task and the value that they may or may not see in doing the work. However, the technique increases expectancy in their ability to complete the task by making the task smaller and more achievable Pomodoro also provides a break at the end of a work session that the student can look forward to which increases the value of completing a task. While there is not much that the Pomodoro method can do to help with impulsivity outside of providing a rigid structure to follow, Pomodoro helps immensely with time management and helps the student from putting off their assignments.

The Pomodoro technique can also help autistic students with academic work that they may find challenging. For example, there is a connection between ASD and lack of motivation to concentrate on a task that is of little interest. Many students with ASD display minimal interest in academic tasks and exhibit disruptive behavior when faced with assignments they don't want to do (Koegel et al., 2010). Some of the factors in the temporal motivation theory are also affected by ASD, including impulsiveness, time perception, the value they see in completing their work, and possibly the confidence they have in their ability to complete the task. Many people with ASD are affected by increased impulsivity in a manner similar to ADHD (Aman et al., 2008). Some research has suggested a connection between impaired time perception and ASD (Casassus et al., 2019) which interferes with completing tasks in time for a deadline. A common symptom of ASD is a lack of motivation to engage in subjects of little interest to them

(DSM-5) so they may see little value in the task at hand. There may also be a connection between ASD and self confidence and psychological empowerment (Chou et al, 2017) that could interfere with task completion. These factors can be managed by the Pomodoro technique in a manner similar to how it helps students with ADHD.

1.3. What are the strengths and weaknesses of this technique?

Logistically, the Pomodoro technique is very simple and low maintenance. The only thing needed for the method is a timer. Although the method is unfit for tasks that are timed, i.e. test situations, it is quite effective in supporting a student with their homework and studying. It improves time management, motivation, and procrastination through the structure provided by the 25 minute work periods followed by a brief break. However, while the Pomodoro method may seem very well suited for the needs of students with ASD and ADHD, the method requires a base level of intrinsic motivation, self-regulation, executive functioning, and self control, all of which are struggles for people with neurodivergence (Goodall et al., 2022). There is very little that keeps the student accountable to their work and if they feel the urge to get off task and do something else, there is not much to prevent that. For the Pomodoro technique to work, the user has to want to do their work - at least to a certain extent. The method helps combat specific symptoms and struggles of ADHD and ASD but could potentially be ill-suited for that demographic due to its requisite of a certain level of self regulation.

2. Body Doubling/Parallel Working

2.1. How does it work?

Body Doubling (also known as parallel working) is a study method that involves a study partner to work alongside to improve productivity. The method is set up by having two people sit side by side (or over a virtual meeting) with a task to work on such as homework (Eagle et al., 2023). The presence of another person facilitates self management and encourages accountability (Burke et al., 2006). Having a body double provides a source of external pressure rather than internal regulation that helps keep the students on task. In the context of school work, a body double may also be helpful in providing support in subjects the other may not be as well versed in. The body doubling technique has been supported by neurobiological research on the concept of mirror neurons which states that the same neurons that fire when someone is executing a task activate when they observe the same task being executed (Acharya and Shukla, 2012). A commonly observable example of this is yawning or feeling the urge to yawn when seeing other people yawn. Similarly, when someone observes another person working and being productive, the mirror neurons related to the task will activate and the individual will feel the urge to follow suit (Rajmohan and Mohandas, 2007). The body double provides not only a source of motivation through the mechanism of mirror neurons but also a measure of accountability which contributes to improved productivity.

2.2. Why does this method work with people with neurodivergence?

The body doubling technique is widely accepted to be geared more towards people with ADHD and is a commonly recommended method to manage tasks that may be difficult due to ADHD. Completing tasks like chores and homework is a very common struggle for individuals with ADHD (DSM-5) and having a body double is a helpful method that has been proven to help with this. Two common obstacles that people with ADHD face include self regulation and motivation, and the reason that body doubling is so effective for individuals with ADHD is likely due to the way that the method alleviates those two struggles. The presence of a body double decreases the need for self regulation through the source of accountability and external pressure to work. It also improves motivation by providing a model of productivity that inspires the other student to work. There is also the neurobiological aspect of mirror neurons that also work

Body doubling is a study strategy mostly used by people with ADHD and much of the literature surrounding this method has a heavy focus on ADHD with less research on how it could help people with ASD. However there is a connection between ASD and irregular mirror neuron systems (specifically, a lack of suppression of the mu wave in EEG measurements) that may interfere with the effectiveness of body doubling (Acharya and Shukla, 2012) (Oberman et al., 2005). This manifests in symptoms of ASD such as difficulty with social cognition, the ability to relate to others, and theory of mind, all of which mirror neurons have been theorized to have an involvement with. In addition, this method can also be helpful for people that don't have ADHD albeit in a more general sense. Having the additional support, accountability, and motivation body doubles provide is helpful for anyone even if it isn't a particular adversity that they may face.

2.3. What are the strengths and weaknesses of this technique?

Body doubling has a lot of strengths for someone with ADHD which include increased motivation and accountability. Individuals with ADHD struggle with motivation themselves and tend to rely more on external factors of motivation (Barkley 1997). Additionally, ADHD causes a dysfunction of executive function and self control that often interferes with productivity (Goodall et al., 2022). To work around this, the method provides an external source of pressure and minimizes the need for self regulation. Having another person to work alongside with ensures a constant source of accountability and support.

On the other hand this method has a lot of aspects that may not work very well with a neurodivergent student, especially students with ASD. The presence of another individual is foundational to this method and while there doesn't have to be much interaction between the two students, social anxiety is very common in people with ASD as well as other forms of neurodivergence (Spain et al., 2018). Difficulty with social interaction could make it hard to set up an arrangement with a body double or could cause discomfort that is distracting while studying. The presence of another student may also be a source of distraction especially for people with ADHD as increased distractibility is a key symptom of ADHD (DSM-5). Additionally, the idea that seeing other people work motivates an individual to work that this

method is based on stems from the concept of mirror neurons. However, there is a correlation between ASD and abnormal mirror neuron systems that suggests that body doubling may be ineffective for people with ASD. Overall there are many aspects of this method that could potentially clash with aspects of ASD as well as with certain features of ADHD and even neurotypical people.

3. Mindfulness

3.1. How does this method work?

Mindfulness, a form of meditation, is a centuries old practice with roots in ancient Asian and Buddhist philosophies. It is important to note that mindfulness is an extremely broad subject with many different approaches and interpretations. Mindfulness has been defined in many different ways but in this paper mindfulness will be defined as the practice of focussing ones mind on their body, emotions and surroundings to achieve a state of improved awareness. Historically, mindfulness was a central part of Buddhism and was believed to be a means to achieve liberation from suffering and a mental state of “omniscience” (Kang & Whittingham, 2010). Eventually, the practice of mindfulness spread to the western world and in the 1970s it became more incorporated into western medicine and science with the help of Professor Jon Kabat-Zinn’s mindfulness-based stress reduction program. Professor Kabat-Zinn, alongside his colleagues from the University of Massachusetts, developed mindfulness based stress reduction (MBSR) by removing mindfulness from its religious and spiritual background and approaching it in a scientific manner to use it as a treatment for stress, pain and illness (Baer, 2003). Throughout the 8-10 week program, patients are taught various mindfulness skills such as body scanning (laying down and closing your eyes for an extended period of time and sequentially focusing on parts of your body) or sitting meditation (sitting down with your eyes closed and focusing on your breathing) (Kabat-Zinn, 2003). While going through these practices, any thoughts that cross your mind are to be acknowledged but attention should be redirected to the point of focus (Baer, 2003). The purpose of these mindfulness practices is to improve focus and reduce stress through sustained attention on one simple thing without letting your thoughts wander too much. There is much evidence to support the benefits of mindfulness and it has been shown to improve symptoms of mental illness, reduce blood pressure, and cardio vascular health (Marquez et al., 2019) (Scott-Sheldon et al., 2019). Many schools have also reported behavioral and academic improvement after the implementation of mindfulness training such as decrease in bullying, lower stress, increase in student camaraderie in a highly competitive academic setting, improved self control, improved critical thinking skills, etc. (Burke & Hawkins, 2012) (Rodgers, 2014) (Burks et al., 2012) (Bond et al., 2013) (Leland, 2015).

3.2. Why does this method work with people with neurodivergence?

Mindfulness has a very heavy focus on improving attentiveness in its users which could be immensely helpful for people with ADHD and ASD (Modesto-Lowe et al., 2015). Both

people with ADHD and ASD have increased difficulty regulating attention and often have difficulty maintaining attention on their homework (DSM-5) (Murphy et al., 2014). Mindfulness has been reported to improve many issues that neurodivergent students struggle with such as executive functioning, attention regulation, and emotional regulation when practiced by neurotypical individuals (Mitchell et al., 2015). There is plenty of evidence that points to the effectivity of practicing mindfulness meditation. Educators with students that have ADHD have reported an improvement in academic success and behavioral conduct in the classroom after the implementation of mindfulness training (Docksai, 2013).

The improvements in behavior are mirrored in the changes that mindfulness causes in brain structure and anatomy. Studies have found that practicing MBSR causes an increase in gray matter in the brain and also improves functional connectivity between related areas (Goodall et al., 2022). Grey matter density refers to the amount of cells in the brain while white brain cells refers to the actual connections between brain cells which connects to other neurons. Mindfulness increases volume of both gray matter and white matter in the brain which leads to improved overall cognition. Studies have shown abnormalities, such as deficiencies and differences in integrity, in both gray and white matter volume and functioning in individuals with ADHD and ASD (Batty et al., 2010) (Weinstein et al., 2011) (Sato et al., 2017) (Hong et al., 2019). These abnormalities have been attributed to symptoms of ADHD and ASD such as inhibition. Improving gray and white matter volume in individuals with a deficit of it through mindfulness practices can lead to an increase in productivity.

3.3. What are the strengths and weaknesses of this technique?

Mindfulness meditation is a unique study practice that focuses more on improving one's mental state rather than their work environment by utilizing techniques such as breathing exercises and yoga. However despite being a more unorthodox study method, it has been proven to increase academic success on multiple different levels. Practicing mindfulness improves executive functioning, attention regulation, emotional regulation, cognition, and minimizes stress levels (source). Additionally Mindfulness provides benefits outside of academics, ie. health benefits such as reduced blood pressure (Scott-Sheldon et al., 2019).

A drawback of Mindfulness as a study technique is the entry barrier it entails. There is a lot of stigma around mindfulness regarding it being a pseudoscience with its ties to religion. Additionally it requires implementing an entire new system into a student's day-to-day life which can be especially hindering for students with ADHD and ASD who struggle with executive functioning. Mindfulness requires consistency and continuity that may be difficult for people with ADHD and ASD to maintain. While the technique itself has a lot of benefits, the practicality of starting it may be a roadblock.

4. Sex and Gender Differences

4.1 What are the differences in neurodivergence between males and females?

When discussing how neurodivergence affects children it is important to note the difference in how it presents and affects males and females differently. The differences can be accounted for by both biological factors as well as societal and developmental influences. For example, males are 4 times more likely to be diagnosed with ADHD and also tend to have more hyperactive traits of ADHD while females are more likely to display more inattentive traits of ADHD (Bölte, 2023). The disproportionate ratio of diagnoses in males and females is likely due to a referral bias, since these hyperactive traits (i.e. fidgeting, volume control issues) are more recognizable and therefore more likely be referred for diagnosis (Mowlem et al., 2018). Similarly, the rate of diagnosed Autism Spectrum Disorder in males is 4 times higher than in females, a difference that is theorized to be attributed to females with ASD being better at “masking” or camouflaging their autistic symptoms, which causes many to go undiagnosed (Ratto et al., 2018) (Kreiser and White, 2014). Some research suggests that the true ratio between autistic males and autistic females may even be closer to 3:1 (Ratto et al., 2018). While referral bias plays a large part in the discrepancy in diagnoses between males and females, there are also biological differences in the brain structure of neurodivergent males and females that attribute to differences in occurrence (Bölte, 2023).

4.2. How does the effectiveness of the study techniques differ between males and females?

Because of the difference in symptomology as well as external factors, the study techniques are likely to have a difference in effectivity between males and females and different aspects of certain techniques may be more effective for one gender or the other. The Pomodoro technique - which aims to maximize focus - may be more successful for females, due to the higher prevalence of inattentive presentations of ADHD in females as opposed to males (Rucklidge, 2014). In ASD there is no consistent evidence for a difference in effectivity between males and females for the Pomodoro technique.

The body doubling technique likely has no difference in effectivity between males with ADHD and females with ADHD. However there is a heavy social factor that comes with body doubling that could be difficult for someone with ASD. Since females with ASD have been found to possess better developed interpersonal and emotional skills than their male counterparts (Rivet and Matson, 2011), this could increase the effectiveness of the body doubling technique for a female with autism over a male with autism. Additionally females tend to have a more developed mirror neuron system than males (Motaqhey et al., 2015) which could lead to a greater overall success of the method with females.

Mindfulness meditation for ADHD is likely equally effective between males and females but more helpful in different aspects. For example, a male with ADHD is more likely to find meditation to be helpful in calming his mind and body and decreasing hyperactivity while a female with ADHD is more likely to find meditation helpful in improving attention and focus. However with ASD, due to the higher prevalence of motor symptoms over cognitive symptoms in males (Bölte, 2023), the focus on bodily awareness in mindfulness may be more helpful for males.

Conclusion

The purpose of this paper was to analyze existing study techniques to identify the most effective strategies for neurodivergent students. Due to the variability between symptomology of different neurodivergent disorders, and furthermore between gender within specific disorders, it is difficult to determine one specific technique or strategy that will surely be effective for all neurodivergent students. However, it can be determined that certain strategies and techniques would be more effective in targeting certain aspects of neurodivergent disorders that impact executive functioning. The Pomodoro technique is effective in targeting struggles with motivation, time management, and inhibition control that can often lead to difficulty with task completion found in students with both ADHD and ASD by introducing a rigid structure to follow and chunking tasks to be more manageable. The Body doubling/parallel working technique also tackles motivation and inhibition control through increased accountability and modeling the task for the student. Mindfulness meditation increases focus and emotional regulation to improve overall productivity.

While this paper investigated strategies to help neurodivergent students, there are countless other options that exist that can relieve symptoms interfering with academic success. Study strategies is only one aspect of the many solutions that exist (eg. medication, student accommodations, skill building therapies, etc.) and within study strategies, there also exists many more than the three discussed in this paper. Currently, there is little existing research regarding the specific topic of study strategies for neurodivergent students but it has great potential to make a significant difference in making academic environments more comfortable and accessible for neurodivergent students.

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Review of the Literature: Causes Behind Health Outcome Differentials Among First World Countries By Ella Chang

Abstract

This paper explores disparities in healthcare outcomes among high-income countries, focusing on the U.S., which, despite its wealth and advanced technology, suffers from high costs and relatively poor health outcomes compared to other high-income nations. In 2021, the U.S. spent around 17.8% of its GDP on healthcare, significantly more than its OECD counterparts. This research investigates the causes of these health outcome differences, focusing on baseline health factors and healthcare system structures. It examines lifestyle factors such as obesity and physical activity, as well as the relevance of "Deaths of Despair," a term for deaths from drug overdoses, alcohol-related liver disease, and suicide, which are alarmingly high in the U.S. It compares different healthcare models in OECD countries, emphasizing the U.S.'s mix of high costs and private sector dominance. The findings point to the need for significant reforms in the U.S. healthcare system to address disparities and improve efficiency. This paper aims to examine the complexities of the U.S. healthcare system and provide insights into potential paths to achieve better health outcomes.

Introduction

In global healthcare, the United States stands out for its unique contradictions. Despite being one of the wealthiest nations with advanced medical technologies, the U.S. healthcare system is full of inefficiencies, marked by excessive costs and relatively poorer health outcomes compared to other high-income countries.

The U.S. healthcare industry is immense, accounting for about 17.8% of the GDP in 2021. It is a major economic force, involving trillions of dollars. Employment-wise, it encompasses a vast range of jobs, from medical professionals to technology experts, and is constantly expanding due to factors like an aging population and technological advances. In research and development, the industry leads with significant investments in new drugs and medical technologies, though these also contribute to high healthcare costs.

An article by Robert Pear in 2002 reported a sharp increase in national health spending in 2000, with a 6.9% rise to \$1.3 trillion, marking the largest one-year percentage increase since 1993. Later, a 2015 Commonwealth Fund report revealed that the U.S. spent more per person on healthcare in 2013 than twelve other high-income nations yet experienced the lowest life expectancy and worst health outcomes. Despite the highest health expenditure at \$9,086 per person annually, the U.S. had a life expectancy of 78.8 years, whereas Switzerland, the second highest spender, had a longer life expectancy of 82.9 years with only \$6,325 being spent per person. According to the Kaiser Family Foundation's 25th Employer Health Benefits Survey, the average annual premium for employer-sponsored health insurance was \$8,435 for individual coverage and \$23,968 for family coverage. And, most recently, in 2021, the U.S. health expenditure per capita was approximately \$12,914, still significantly higher than its OECD

country counterparts. In Figure 1, the U.S. stands out significantly with the highest spending, reaching approximately 17.8% of its GDP in 2021, with the next highest being Switzerland at around 11.8% and Germany at 12.8%, while the OECD average is 9.6%. These investments have not led to superior health outcomes. Such discrepancies raise critical questions about the underlying structures and policies governing the U.S. healthcare system.

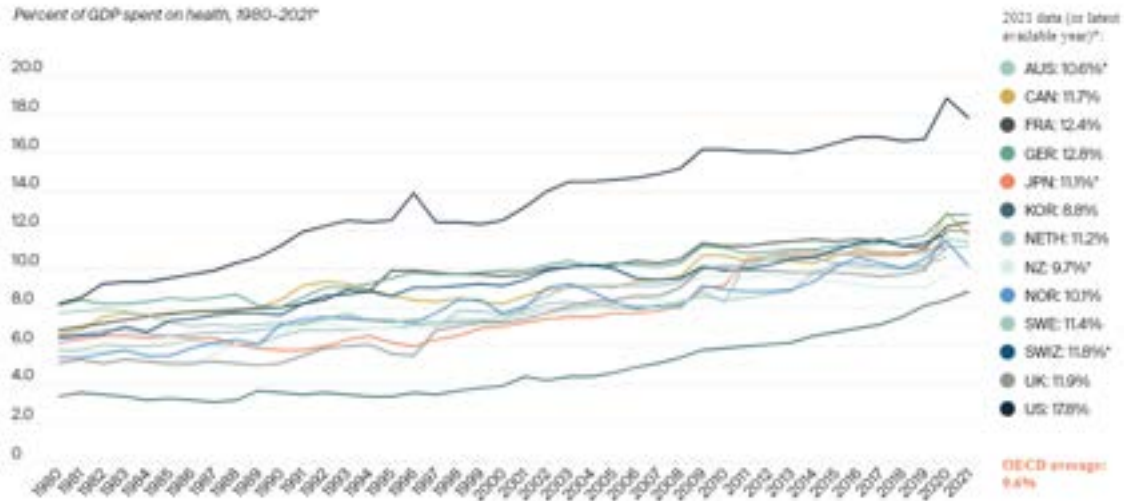


Figure 1: Percent of GDP spent on health, 1980-2021

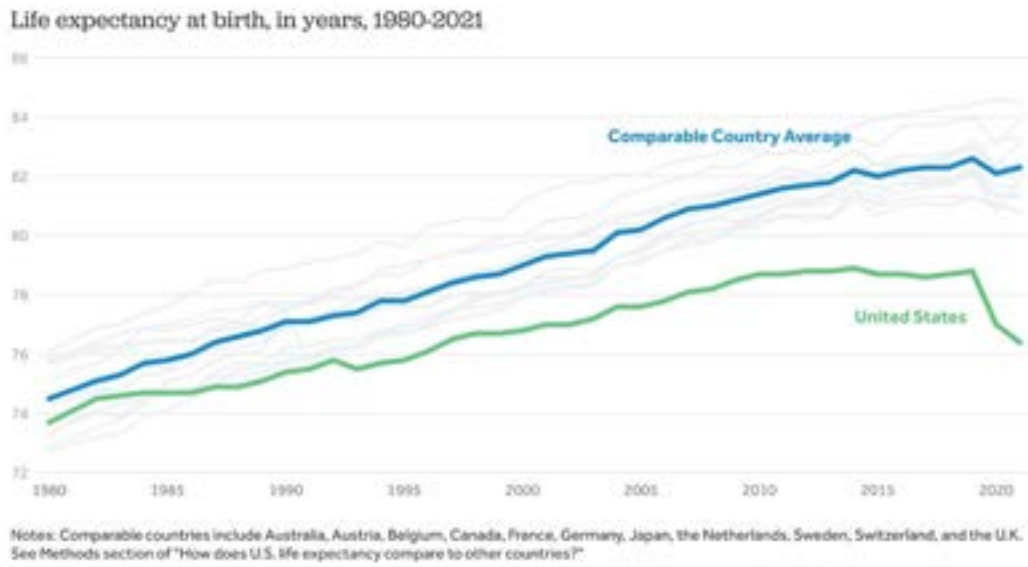


Figure 2: Life expectancy at birth, in years, 1980-2021

Figure 2 displays the life expectancies of comparable countries to the U.S. Although the life expectancy in the U.S. is increasing with its comparable country counterparts, a significant gap remains. Furthermore, the sharp decline in 2020, which is primarily attributed to deaths from the pandemic, is a much greater dip.

Expanding on this, the COVID-19 pandemic, which although was a challenge for healthcare systems worldwide, revealed the U.S. healthcare's deeper systemic issues. For

instance, life expectancy in the U.S. declined greatly, with studies showing a drop to 77 years in 2020 – a significant decrease compared to the OECD average. This decline in life expectancy, along with the highest rates of avoidable deaths, maternal and infant mortality, and chronic conditions among high-income nations, suggests a struggling healthcare system.

Additionally, the U.S. healthcare system is involved in many controversies, primarily around cost and accessibility. High healthcare and insurance costs create barriers and disparities. Drug pricing, especially for new treatments, sparks debates over ethics and affordability. The mix of private and public healthcare raises questions about quality of care versus profit motives, and technological advancements bring ethical and logistical challenges, such as data privacy and the cost of high-tech treatments. An example of these inefficiencies and controversies is the high cost of drugs in Medicare, particularly for physician-administered drugs. This issue is demonstrated by the case of Aduhelm, an Alzheimer's drug priced at \$56,000 annually. With over 95% of Alzheimer's patients being covered by Medicare, drug manufacturers like Biogen can set high prices, knowing Medicare's policy is to pay what other customers pay. Efforts in Congress to change these payment policies have been unsuccessful, leading to rising costs. Proposals such as authorizing private insurers to negotiate drug prices and government regulation of prices have been suggested, but they risk impacting patient access and pharmaceutical development.

This all raises the question: What are the causes behind health outcome differentials among first-world countries? This paper aims to explore the causes of current healthcare challenges, with the ultimate goal of understanding how the United States, despite its vast resources and advancements in medical technology, can realign its healthcare system to better serve the health and well-being of the population.

Review of the Literature

Baseline Health

This overview looks at important lifestyle factors like weight and exercise, the impact of drug consumption, and the phenomenon known as "Deaths of Despair" on public health. By examining these elements, we can gain valuable insights into how different determinants of health contribute to disparities in health outcomes and quality of life across various populations.

Weight and Exercise

The impact of lifestyle factors on global health and well-being has been the subject of extensive research in recent years. The balance between body mass and physical activity levels plays a crucial role in determining an individual's overall health.

The studies by Walpole et al. (2012) and Bauman et al. (2009) offer valuable insights into two significant lifestyle aspects: body mass and physical activity.

Walpole et al. (2012) conducted an innovative study to estimate global human biomass, emphasizing the growing prevalence of overweight/obesity rates, especially in the U.S. Additionally, Recent research by McIver KL et al. (2020) using data from the TEDDY study provides new insights into physical activity levels among 5-year-old children across various

countries and regions within the U.S, revealing that U.S. children are generally less active and more sedentary compared to their European peers.

Bauman et al. (2009) examined the prevalence of physical activity across 20 countries, highlighting its critical role in influencing health outcomes. The study found that physical inactivity is a major risk factor for chronic diseases such as heart disease, diabetes, and certain cancers. Countries with higher levels of physical activity tend to have lower rates of obesity and related health issues, demonstrating the connection between exercise and weight management. Regular physical activity helps regulate body weight and improves metabolic health, whereas physical inactivity often leads to weight gain and increased chronic disease risk.

In conclusion, the U.S.'s baseline health, marked by higher obesity rates and lower physical activity levels, plays a significant role in its differing health outcomes. Addressing these lifestyle factors is crucial for enhancing the nation's health and reducing the prevalence of chronic diseases.

Drug Consumption & Deaths of Despair

Drug consumption significantly impacts healthcare outcomes, leading to higher rates of chronic diseases and mental health challenges, as well as contributing to the rise in "Deaths of Despair." This section explores the broad implications of drug use on public health, highlighting its effects on overall healthcare systems and societal well-being.

According to a report measured using Disability-Adjusted Life Years (the sum of years of lives lost and years lived with disabilities) in 2019, the U.S. leads the world in illicit drug consumption, with about 6.7 healthy years of life lost due to participation in such activities. This high rate of drug use has significant implications for public health and the burden on healthcare resources. Furthermore, global and domestic trends indicate a rise in drug use, driven by stressors like the pandemic, economic instability, etc.

The study by Martins et al. (2015) analyzes global trends in unintentional drug overdoses, emphasizing the growing public health issue. It shows an increase in drug-related deaths, with a notable shift towards prescription opioid overdoses, as well as highlights the U.S. experiencing a higher rate of drug overdoses compared to other countries. Moreover, the findings underscore the rising concern of drug overdoses not only as an urban problem but also affecting rural areas, with substances like cocaine, prescription opioids, and heroin being the most involved in these unintentional overdoses. Similarly, a data brief by Tikkanen et al. (2020) highlights the comparative burden of mental health issues and substance use in the United States relative to other high-income nations, positioning the U.S. among the nations with the highest rates of reported mental health issues, resulting in the U.S. facing poorer health outcomes.

Furthermore, Schnell conducted a study that examined the impact of the illegal secondary market for prescription opioids on physicians' prescribing practices and patient health outcomes. Strict prescribers become more cautious to reduce unnecessary prescriptions and abuse. In comparison, lenient prescribers prescribe more, in part to prevent patients from obtaining them illegally elsewhere. This is also partially explained by Currie's research, which explores the effects of competition on physician prescribing behavior. Using detailed panel data, Currie found

that increased competition led to more opioid prescriptions for patients, highlighting how competition among healthcare providers and potentially the illegal secondary market drives demand and influences practice styles, contributing to inefficiencies and lower healthcare quality in the US by promoting unnecessary and harmful opioid overprescribing as it can cause addiction and overdose. Considering this, the U.S. needs strategies that balance effective pain management and drug prescription to prevent opioid misuse.

The data below from BioMed Central presents a breakdown of the risk of suicide by substance use disorder category, considering factors of different drug types, both individually and in combination. The table shows that the odds of suicide are significantly higher in individuals with a substance use disorder compared to those without, with the highest odds being observed in individuals using a combination of alcohol, drugs, and tobacco.

Substance use disorder category	Odds ratio ^{a*}			Adjusted odds (adjusted for age, gender, poverty level, education, Charlson index, psychiatric diagnoses)		
	OR	CL ^{b*}	p-value	aOR	CI	p-value
Alcohol only	15.5	13.1, 18.4	0.001	5.8	4.7, 7.1	0.001
Drug only	11.3	8.8, 14.4	0.001	5.3	3.9, 7.0	0.001
Tobacco only	3.5	3.1, 4.0	0.001	2.0	1.7, 2.3	0.001
Alcohol + drug	21.8	16.2, 29.3	0.001	8.1	5.7, 11.5	0.001
Alcohol + tobacco	19.5	15.8, 24.2	0.001	6.1	4.8, 7.9	0.001
Drug + tobacco	14.1	10.2, 19.6	0.001	5.0	3.4, 7.4	0.001
Alcohol + drug + tobacco	30.7	23.3, 40.6	0.001	11.2	8.0, 15.6	0.001

a* - All conditional logistic regression models are conditions on site

b* - CI denotes 95% confidence interval

[Table 2 Risk of suicide by substance use disorder category, whole sample](#)

Furthermore, the United States is notable for its pattern of "Deaths of Despair" (DoD)—a term describing fatalities due to drug overdose, alcohol-related liver disease, and suicide. This trend greatly contrasts with the declining mortality rates observed in other high-income countries prior to the COVID-19 pandemic, highlighting significant baseline health inequalities. The review by Beseran et al. explores the social determinants behind these disparities, such as economic instability, occupational hazards, educational disparities, geographical isolation, and racial/ethnic inequities. Correspondingly, Case and Deaton (2018) challenge the view that the

DoD crisis is only about drugs, with their analysis presenting similar insights into DoD's relation to deeper societal problems, not just standalone health issues. For instance, if economic hardships were solely to blame, mortality rates would be expected to fluctuate with economic downturns and recoveries. However, this was not the case, as mortality rates continued to rise even when the economy was recovering, emphasizing how issues of substance use, mental health, and socioeconomic factors are connected. While economic downturns can increase stress and instability, leading to more substance abuse and mental health problems, the continued rise in death rates during economic recovery shows that these problems are deeply within society. Multiple factors like ongoing job insecurity, lack of quality healthcare, educational inequalities, and systemic racial and ethnic disparities create an environment full of despair, regardless of the economy. The ongoing rise in deaths highlights the need to address these social issues to effectively combat the crisis.

Healthcare System & Access

Healthcare systems are essential in determining how people receive medical care and how accessible it is within a country. These systems include the organizations and resources that provide healthcare services to the population. The way a healthcare system is structured and managed has a significant impact on overall health outcomes. Different countries use various healthcare models, which influences how healthcare is funded, regulated, and delivered. Understanding these systems is needed to evaluate healthcare access and outcomes, especially in first world countries where differences in system design can lead to differing levels of healthcare quality and accessibility.

A research study by Wendt et al. examined health care systems in 29 OECD countries and identified five main types based on data related to quantity and institution:

Supply and choice-oriented public systems prioritize doctors' autonomy, offer diverse healthcare providers, and rely on public funding. Patients have freedom in provider selection, with specialists often operating on a fee-for-service basis, emphasizing choice and accessibility. Countries that have adopted this model include Australia, Austria, Belgium, the Czech Republic, Germany, France, Ireland, Iceland, Luxembourg, and Slovenia.

Performance and primary care-oriented public systems emphasize primary care services with a focus on performance management, prevention, and quality care. Public financing is prominent in these systems, with limited access to specialists and strong gatekeeping mechanisms ensuring quality care provision. Countries following this model include Finland, Japan, Korea, Norway, New Zealand, Portugal, and Sweden.

Regulation-oriented public systems rely on medium public financing and strong public regulation governing provider access and services. Limited patient choice, low out-of-pocket costs, and access regulations characterize these systems. Countries following this model include Canada, Denmark, Spain, Italy, the Netherlands, and the United Kingdom.

Low supply and low performance mixed-type systems require improvements in infrastructure and service delivery due to challenges in resource availability and care quality,

despite medium public funding. Countries adopting this model include Estonia, Hungary, Poland, and Slovakia.

Supply and performance-oriented private systems focus on performance management through a predominantly private sector approach. These systems prioritize private financing, high healthcare supply, and cost-sharing regulations. Countries following this model include Switzerland and the United States.

While Switzerland also has the same general health care system like the U.S., there are several factors that contribute to its superior health outcomes. Switzerland mandates universal health coverage with subsidies for low-income individuals, ensuring broad access, while the U.S. lacks this, leading to disparities. Switzerland's regulated insurance market requires standardized benefits, focusing on quality and cost-efficiency, unlike the more fragmented U.S. system. Additionally, Switzerland has pricing transparency and controls healthcare costs, which reduces financial burdens on patients. In contrast, the U.S. faces higher costs, less accessible preventive care, and inefficiencies. These differences potentially explain Switzerland's higher healthcare ranking compared to the U.S.

Additionally, the Oregon Health Insurance Experiment, led by Finkelstein et al. (2012), revealed that extending Medicaid to low-income, uninsured adults significantly increased hospital, outpatient, and drug utilization; reduced out-of-pocket expenses and medical debts; and enhanced self-reported mental and physical health. These findings suggest Medicaid offers many benefits beyond non-Medicaid alternatives available through safety-net options. This is relevant to why the U.S. has differing healthcare outcomes compared to other countries with universal healthcare systems, where consistent access to care leads to better overall health outcomes and lower costs. The U.S. system is more fragmented and relies on programs like Medicaid, therefore often resulting in inconsistent access and disparities.

Conclusion

This literature review explored disparities in healthcare outcomes among high-income countries, focusing on the U.S. Baseline health factors, such as higher obesity rates and lower physical activity levels in the U.S. contribute to poorer health outcomes. Additionally, the U.S. leads in illicit drug consumption, which is perpetuated by the existence of secondary markets and competition among physicians, resulting in chronic diseases and deaths of despair, which connects to mental health challenges. Furthermore, the U.S. healthcare system's structure, with its mix of private and public funding, creates barriers to access and drives up costs. Unlike countries with universal coverage, the U.S. system's fragmentation leads to inefficiencies and disparities.

While this paper provides a general analysis, it could explore deeper into the causes of the identified baseline factors and into the different health care systems in detail through recognizing specific parts of varying systems that are working well. It could also explore the role of healthcare technology, how it affects outcomes, and where the United State's advancements stand compared to other first world countries.

Next steps for the U.S. should include conducting analyses of high-performing healthcare systems to identify best practices and exploring ways to enhance baseline health through targeted interventions. Hopefully by taking these steps, the U.S. can provide more comprehensive solutions to the healthcare challenges they face.

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Deep Learning-based Lesion Segmentation and Classification Using Haralick Texture Feature Maps on Prostate MRI By Rishil Kadakia, Dang Bich Thuy Le, Ram Narayanan , Meredith Sadinski , Aleksandar Nacev , Yuling Yan, and Srirama Venkataraman

Abstract

Accurate identification and classification of prostate cancer lesions are crucial for effective diagnosis and treatment planning, prompting investigation of deep learning-based approaches to classification of prostate MR images. Haralick texture features (HTF) for prostate cancer detection have shown promise in T2-weighted MR images (T2WI). Here, we evaluate the potential of combining axial T2WI with HTF into a single multi-channel image as input to a deep learning framework to segment prostate cancer lesions and classify their aggressiveness using Gleason score as ground truth. 3D, T2WI of 344 patients from the ProstateX dataset were resampled to 160 x 160 x 24 voxels with a spacing of (0.5, 0.5, 3) mm. Images underwent normalization and rescaling to 64 gray levels. Gray level co-occurrence matrices were computed on transverse, 2D slices to create four texture maps (Contrast, Energy, Correlation, and Homogeneity). A modified Retina U-Net was utilized, where the U-Net framework was used for lesion segmentation, independent of their lesion class. Bounding box (BB) regression techniques were applied to refine coarse detection derived from the U-Net decoder feature maps, followed by BB classifier prediction for lesion class determination. The model demonstrated an AUC/accuracy/sensitivity/specificity of 0.87/0.806/0.923/0.776 respectively on the patient level of the ProstateX test dataset. The model works well on independent images acquired from multiple centers from our own clinical study that tested the generalizability of the algorithm. Reported metrics show promise for the use of HTF maps in deep learning frameworks for identification, segmentation, and classification of prostate cancer lesions. Moving forward, the potential of other network architectures can be explored to improve the specificity of the model. Additionally, training data from additional sources can be integrated to enhance robustness to variations in imaging protocol and patient demographic factors.

Introduction

Prostate cancer is one of the most common cancers among men worldwide. From 2013-2019, the 5-year survival rate for those with local or regional prostate cancer was greater than 99%; however, for those diagnosed with prostate cancer that had metastasized, the 5-year survival rate dropped to 34% (American Cancer Society). Therefore, accurately identifying suspicious regions is essential for precise diagnosis, leading to timely and effective treatment. Automatically identifying lesion locations on imaging, as well as aggressiveness of lesions, could reduce reading times, reduce effects of inter-reader variability, enabling the patient to get results and treatment earlier, further preventing unnecessary biopsies.

However, localization of biopsy targets is still challenging because clinical analysis of MR images for identifying potentially cancerous regions despite global standardization efforts in using PI-RADS, has been largely qualitative (Winkel et al.). Quantitative image analysis

techniques, such as texture analysis, provide an alternative method that can be more reproducible and less subjective (Varghese et al.). Texture analysis is a technique to extract frequencies of local spatial variations in signal intensity, thus quantifying pixel relationships within regions of interest. One of the most common image texture analysis techniques is Haralick texture analysis, being studied as quantitative characterization for cancer detection in breast cancer (Chitalia and Kontos; Ahmed et al.; Yasiran et al.; Wu et al.), colon cancer or rectal cancer (Caruso et al.; Chaddad et al.; Soomro et al.; Peyret et al.) or prostate cancer (Nketiah et al.; Daniel et al.; Brynolfsson et al.; Shiradkar et al.). Specifically on T2-weighted, 3T prostate MRI, according to Wibmer et al., several Haralick based texture features show promise for prostate cancer detection. They explored the utility of Haralick texture analysis on prostate MRI, aiming to differentiate between non-cancerous prostate tissue and prostate cancer, as well as to distinguish between different Gleason Scores. Their findings revealed significant associations between certain texture features derived from T2-weighted images and prostate cancer presence and aggressiveness. This study sheds light on the potential of texture analysis as a complementary tool for prostate cancer detection and risk stratification, offering valuable insights for improving diagnostic accuracy and patient management strategies.

Additionally, several research papers have explored the development and application of deep learning algorithms for prostate cancer diagnosis and classification. Schelb et al. compared PI-RADS assessment on the detection and segmentation of lesions suspicious for clinically significant prostate cancer with a two dimension U-Net model trained on T2-weighted MRI scans. Their results demonstrated comparable performance between the two methods, with the deep learning system demonstrating sensitivity ranging from 92% to 96% at specific thresholds. Kott et al. developed an 18-layer-deep residual convolution neural network learning algorithm for diagnosing prostate biopsy specimens. The algorithm operated at two classification levels: coarse (benign vs malignant) and fine (benign vs Gleason 3 vs Gleason 4 vs Gleason 5), achieving 91.5% accuracy at the coarse level and 85.4% at the fine level. However, the model had difficulty distinguishing between Gleason patterns 3, 4, and 5. Bulten et al. utilized a modified U-net architecture, and deepened it to six levels, introduced additional skip connections within each layer block, and incorporated up-sampling operations in the expansion path, to predict biopsy grade groups. The model achieved an agreement of 0.918 with consensus grade groups and outperformed many pathologists. These studies have showcased the efficacy of deep learning models in accurately diagnosing and classifying prostate cancer lesions. However, existing models still grapple with challenges in accurately distinguishing between different grades and aggressiveness of lesions, highlighting the ongoing need for advancements.

The purpose of this study is to evaluate the potential of Haralick texture maps, together with axial T2WI, as input channels to a deep learning framework to not only automatically locate and segment prostate lesion areas, but also predict their aggressiveness. Building on the methods and discoveries from key research, by adding Haralick texture features as input to a modified Retina U-Net in order to provide more information, our study aims to bring new insights in diagnosing prostate cancer, ultimately helping to improve patient care and clinical decisions.

Materials and Methods

Data

The study used 3D T2-weighted images from the publicly-available ProstateX dataset, comprising 344 patients. The images were acquired using Siemens 3T MRI scanners (MAGNETOM Trio and Skyra) without an endorectal coil, with a spatial resolution of around 0.5 mm in plane and a slice thickness of 3.6 mm.

An additional 30 datasets collected from our own IRB-approved study of patients who underwent a prostate biopsy procedure were used to further evaluate the algorithm. These datasets were used to assess performance on independent data from a center not used in the training.

Pre-processing: Images were resized to 160 x 160 x 24 voxels with a spacing of (0.5, 0.5, 3) mm. B-Spline interpolation of third order was employed for image interpolation, while nearest neighbor interpolation was used for binary segmentation masks.

Lesion Segmentation - Ground Truth: As ProstateX provides only the center position of each lesion, we used the ground truth of lesion masks labeled by the Department of Advanced Biomedical Sciences of the University of Naples Federico II⁵ (Cuocolo et al.), with lesion-by-lesion quality check. For the datasets whose lesion masks were not labeled by Cuocolo et al., we applied the technique of automated lesion region growing from a seed (Pellicer et al).

Four classes of prostate cancer aggressiveness were designated based on Gleason score (GS) and named Gleason Grade Groups (GGG): GGG0 (benign), GGG1 (GS 3+3), GGG2 (GS 3+4), and GGG3 (GS 4+3 and above).

For the ProstateX challenge test set with no lesion GS available, we used them to train segmentation but not classification of GS.

Methodology

Gray Level Co-occurrence Matrix: Gray Level Co-occurrence Matrix (GLCM) is a two dimensional histogram that captures the frequency of co-occurrence of two pixel intensities at a certain offset. The values in GLCM are the counts of frequencies of the neighboring pairs of image pixel values. We make GLCM symmetric for the best performance of texture calculations, and for overcoming the problem of the window edge pixels. The GLCM is normalized by dividing by the total number of accumulated co-occurrences. In normalized symmetrical GLCM, the diagonal elements all represent pixel pairs with no gray level difference and the farther away from the diagonal, the greater the difference between pixel gray levels (Haralick et al.; Hall-Beyer).

Haralick Texture Measures: Haralick et al. proposed 14 different texture feature extraction measures from GLCM to evaluate the relationship between image pixels. Texture measures are the various single values used to summarize the normalized symmetrical GLCM in different ways. These texture features are correlated with each other. They are divided into three groups that are independent of each other: Contrast group that uses weights related to the

distance from the GLCM diagonal, Orderliness group that measures how often a given pair of two gray levels occur within a window, and Descriptive Statistics group (Hall-Beyer). We limited our analysis to Energy (Orderliness group), Correlation (Descriptive Statistics group), Contrast and Homogeneity (Contrast group) based on prior literature identifying them as useful for distinguishing cancer by outcomes (Wibmer et al.). Equations to calculate these measures are shown in Table 1.

Table 1: Formula to calculate Energy, Contrast, Homogeneity, and Correlation, where i, j are the row and column number, $P_{i,j}$ is the value for the cell i, j of normalized GLCM. Note that when GLCM is symmetrical, $\mu_i = \mu_j$ and $\sigma_i = \sigma_j$.

Energy	Contrast	Homogeneity	Correlation
$\sqrt{\sum_{i,j=0}^{N-1} P_{i,j}^2}$	$\sum_{i,j=0}^{N-1} P_{i,j}(i-j)^2$	$\sum_{i,j=0}^{N-1} \frac{P_{i,j}}{1+(i-j)^2}$	$\sum_{i,j=0}^{N-1} P_{i,j} \frac{(i-\mu_i)(j-\mu_j)}{\sqrt{\sigma_i^2 \sigma_j^2}}$
where $\mu_i = \sum_{i,j=0}^{N-1} iP_{i,j}$ and $\sigma_i = \sqrt{\sum_{i,j=0}^{N-1} P_{i,j}(i-\mu_j)^2}$			

In this study, we assess the variation in pixel-to-pixel relationship for different regions of the image by generating texture feature maps using a sliding window technique. For each pixel in the image, the four texture metrics were calculated for an image window, centered around the pixel and the resulting values assigned to that pixel position.

The images were normalized and rescaled to 64 gray levels. Then the GLCM was computed in 4 directions on transverse, 2D slices. For each T2WI, four texture maps (Contrast, Energy, Correlation, and Homogeneity) were created.

Normalized T2WI, the four corresponding texture feature maps, and a binary prostate segmentation mask were combined into a single multi-channel image for the deep-learning model, shown in Figure 1.

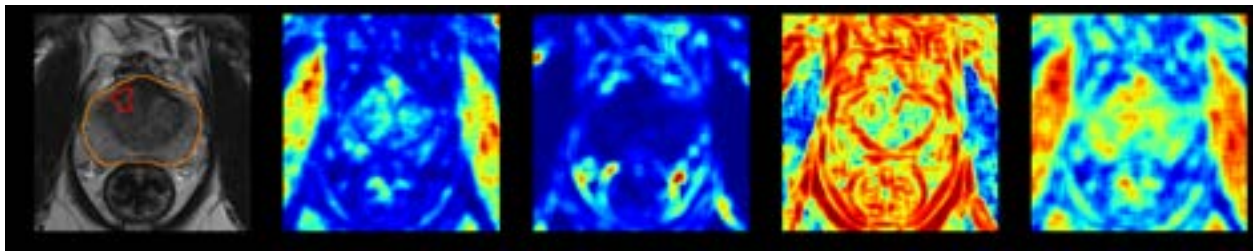


Fig. 1: Input channel of deep learning model: T2-weighted, axial images with prostate segmentation in orange and lesion mask with GS of 3+4 in red, and its Energy, Contrast, Correlation, and Homogeneity feature maps respectively.

Retina U-Net: The Retina U-Net architecture merges elements of RetinaNet, an object detector, with the U-Net architecture, a semantic segmentation model, for medical image analysis Jaegar et al.. It incorporates a backbone network, typically a pre-trained CNN like ResNet or VGG, to extract hierarchical features from input medical images. A Feature Pyramid Network (FPN) generates multi-scale feature maps to handle objects of varying sizes, enhancing object detection performance. Inspired by U-Net, a top-down pathway combines high-resolution features with low-resolution ones to provide both local and global context, aiding in accurate object localization and segmentation. A semantic segmentation branch operates on high-resolution features to predict pixel-wise segmentation masks for different object classes, while an object detection branch, based on RetinaNet's architecture, detects and categorizes objects. Integration of the outputs from both branches refines object localization and classification, leveraging pixel-wise supervision signals. The model is trained end-to-end for both tasks, effectively utilizing pixel-wise supervision signals and enhancing performance in medical image analysis.

Training Flow: In this study, we used a modified Retina U-Net, proposed in Pellicer et al.. The U-Net architecture segments the lesions present in the image irrespective of their class. BB Regression operates on the feature map generated by the decoder of the U-Net. Its primary function is to refine the coarse lesion detections obtained by the segmentation map. By adjusting the bounding box coordinates based on learned regression parameters, BB Regression ensures that the predicted bounding boxes closely align with the actual boundaries of the lesions. BB classifier predicts the class of each segmented lesion. The BB Classifier assigns a class label to each lesion, such as benign or various levels of cancer aggressiveness based on Gleason score. In addition, the Haralick texture maps were added in the model input. Figure 2 shows the training flow of the model.

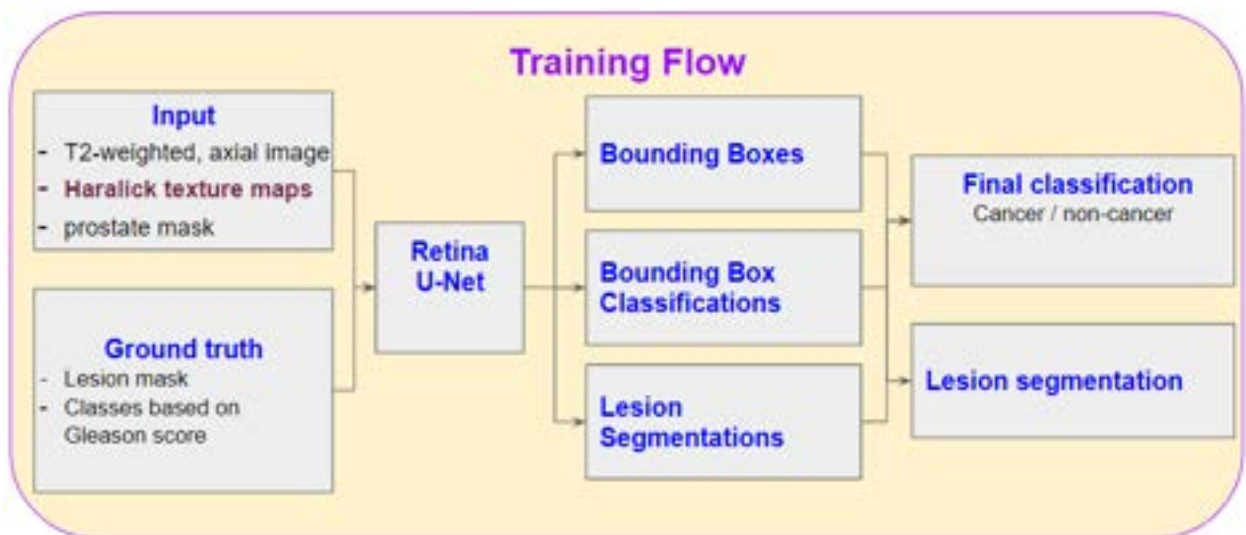


Fig.2 Training flow of lesion segmentation and classification model.

Experiments and Results

To evaluate the effects of Haralick texture maps, we trained two models using the same setup as outlined in Figure 2’s training flow. The only difference is in the configuration of input channels: one model incorporates Haralick texture maps, whereas the other model excludes them. In both models, the patient dataset was partitioned into 247 in training, 35 in validation, and 62 in test.

Table 2 presents the performance of two models on the patient level using the ProstateX test dataset. The metrics illustrate that the model trained with Haralick texture maps outperforms the one trained without incorporating them. Additionally, the performance of our model surpasses that reported in Pellicer et al., whose AUC, sensitivity, and specificity are 0.865, 0.923, and 0.688 respectively. In this study, they employed the Retina U-net architecture but with a notable enhancement of training it with a dataset size 1.5 times larger (ProstateX and their own private clinical data) and incorporating all available image contrasts, including DWI and ADC maps, but excluding Haralick texture maps. We hypothesize that the inclusion of texture maps into the model input enhances diagnostic information, thus contributing to improved performance.

Table 2. The performance of the two models on the patient level on the ProstateX test dataset. One model utilizes Haralick texture maps as input channels, while the other does not.

Model	AUC	Accuracy	Sensitivity	Specificity
With Haralick texture maps	0.87	0.806	0.923	0.776
Without Haralick texture maps	0.825	0.711	0.923	0.625

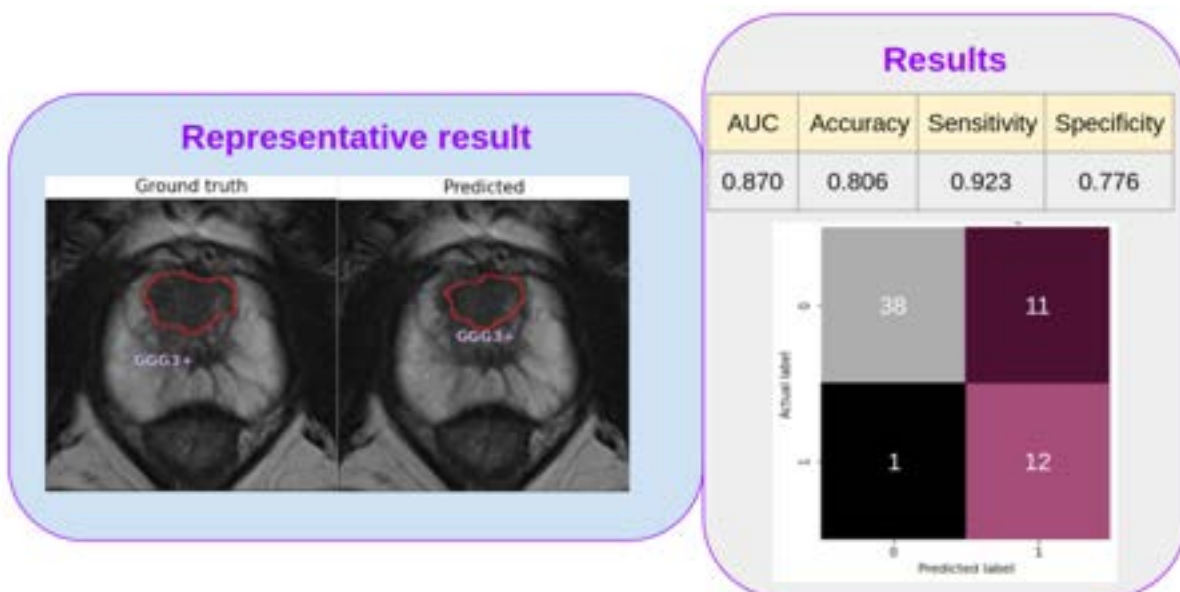


Fig. 3. Test result on ProstateX test set. Left: a representative result with lesion segmentation in red and GS prediction of GGG3+ where: left: ground truth and right: prediction. Right: Evaluation of model on ProstateX test set.

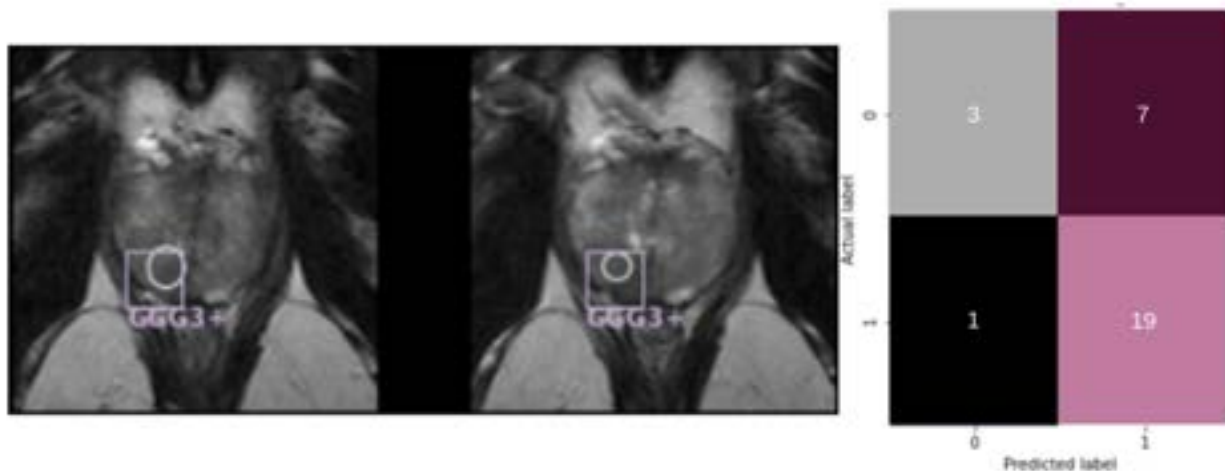


Fig. 4. Test result on our own clinical study. Left: a representative result with BB box locating lesions on 2 slices and prediction of GGG of 3+ in purple. Regions of interest in white were annotated by a radiologist to take biopsy and pathology reported as GS of 4+3. Right: Confusion matrix of testing model on 30 patients.

The identified lesion locations and class predictions for both test sets are shown in Figures 3 and 4. Figure 3 displays a representative image with predicted and ground truth labels for a ProstateX test case, along with the confusion matrix for the ProstateX test set. In figure 4, a representative image and the associated confusion matrix illustrate results from our independent clinical study that tests the algorithm’s generalizability on data acquired from a different center.

Discussion

The integration of Haralick texture feature maps within a deep learning framework has yielded promising results for lesion localization, segmentation, and Gleason score prediction. Notably, our approach exhibited high predictive accuracy on ProstateX test datasets, and demonstrated effectiveness even on a smaller dataset from a different center. However, to further validate its generalizability, comprehensive evaluation on datasets collected from multiple centers with diverse acquisition protocols is deemed essential. As part of our ongoing efforts, we are planning to explore alternative architectures to enhance lesion segmentation and classification, particularly at the lesion level.

Conclusion

In this study, we incorporated Haralick texture maps as four input channels into a deep learning architecture. This strategy proved to be valuable in locating, segmenting, and predicting the Gleason score of lesions. Our findings, particularly at the patient-level, have revealed

promising outcomes, supported by favorable values of AUC, sensitivity, and specificity. This suggests the potential of the proposed method for accurately identifying suspicious regions that merit biopsy acquisition. To advance the field, future research endeavors will focus on exploring alternative network architectures to enhance the model's specificity. Additionally, efforts will be directed towards integrating data from diverse institutions during both training and testing phases, aiming to establish robustness against variations in protocols and patient populations.

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Sabermetrics in Cricket By Tanav Prabhu

Abstract

The goal of this paper was to use sabermetric ideologies in the sport of cricket. To do this, a model was created from analyzing and fine-tuning previous IPL 2023 games. Using this model, the aim was to find the dream starting lineup from the IPL 2023 season. Since this has already been done by various other sources, the paper expands by finding the. In addition, the paper identifies the most underpaid players from the season and constructs the best possible team out of them, recognizes the best performances from individual players, and finally explains how certain teams did better than expected, and vice versa.

1 Introduction to Cricket

Cricket is a gentleman's sport that originated in 16th-century England. With a team of 11 players facing off against one another in a contest of bat and ball, the sport grew rapidly in popularity, beyond just England. Now, cricket is a sport followed by billions, becoming the 2nd most popular sport in the world. And the new T20 World Cup played in the United States and West Indies has caused the sport to grow even more, in part due to some monumental upsets.

The stadium involves a pitch (22 yards long and 10 feet wide) surrounded by a grass ovular field with varying dimensions. 2 batsmen on opposite ends of the pitch attempt to score runs by hitting the ball and running between stumps. If they hit the ball to touch the boundary, it is counted as 4 runs, and if they manage to get the ball over the boundary without touching the ground, it is counted as 6 runs.

Different bowlers employ different techniques to get the batsmen out. Pace bowlers are those who bowl the ball at a fast pace. They often change the pace to trick the batsmen and use the ball's swing to make it deviate from its linear path. Spin bowlers typically bowl the ball slower, but make up for that in the amount of variations they use.

These bowlers and fielders try to get the batsmen out in many ways. If the ball is caught without touching the ground, the batsman is caught out. If the fielder can hit the stumps on the other end, while the batsman is still running, the batsman is run out. If the batsman doesn't keep their foot on the crease, the wicketkeeper can get them out via stumping. Finally, if the ball's path is toward the wicket and the batsman puts their leg in front of it, they are out by LBW (Leg Before Wicket). Keeping these in mind, both teams use different strategies at different times in the game.

Cricket was a fascinating sport since it involved not only strength and talent but also strategy and deliberate planning. Early on, only test matches for up to five days were played. But in the twentieth century, fifty-over games, or one-day internationals (ODIs), were created to shorten the playing time. And in 2003, twenty over games, or twenty20 (T20), were created as a way for an even shorter game to be played. The T20 games are the main reason cricket is growing today, even competing with similar sports like baseball.

In India specifically, the Indian Premier League (IPL) was a domestic T20 tournament created as a way to train new talent, as well as give foreign players a way to improve. Each team is allotted INR 100 crores (or about 12 million dollars) to select a squad of 25 players maximum,

of which a maximum of 8 overseas players are allowed. In the starting XI, or the starting 11, of each team, only 4 overseas players can be selected. Additionally, the IPL consists of 10 regional teams across India representing a certain area of the country: Chennai Super Kings, Delhi Capitals, Gujarat Titans, Kolkata Knight Riders, Lucknow Super Giants, Mumbai Indians, Punjab Kings, Rajasthan Royals, Royal Challengers Bengaluru, and Sunrisers Hyderabad. This regional pride and the fact that the matches being played across India made the IPL one of the most valuable sports leagues in the world.

This paper analyzes and provides insights into the 2023 season of the IPL.

2 Framework

In the early 2000s of baseball, Billy Beane started looking into how to optimize his low-budget team, the Oakland Athletics, to try and win. Using statistics, he led his team to a record 103-59 season. They also won 20 games in a row during this stretch. His ideology was to use sabermetrics, or advanced sports statistics, to buy "wins" rather than well-known players. He termed this strategy "Moneyball". In this chapter, I'll apply sabermetrics to cricket, specifically the 2023 season of the IPL, to determine undervalued players that can form a dream starting lineup.

For the IPL 2023, data from each match would be needed to examine the players accurately. cricsheet.org was used, as it had the ball-by-ball data from all IPL matches from 2007 to 2023. The data was restricted to the most recent season, which contained 74 matches.

To analyze players from the ball-by-ball data, some custom metrics needed to be defined. There would need to be an overall score to indicate how much a player contributed to the match: this was called a "total score". This would need to consist of a batting score and a bowling score. Because some players played more games than others, as well as certain teams playing in the playoffs, an average across all the matches would need to be taken.

3 Batting and Bowling Scores

To determine which of the batting stats are most relevant, various research articles and blogs online were examined. ESPNcricinfo was helpful for its page on IPL 2023 records ("Indian Premier League, 2023 - Stats and Records"). To extract the data from the cricsheet, the pandas library was used.

First, the amount of runs scored was assessed. To correctly get the number of runs scored off the correct amount of balls from the data frame, no-balls (where the bowler makes an invalid delivery typically by stepping over the crease) and wides (where the bowler bowls the ball such that the batsman can't reach it) had to be taken into account. To make it simple, 1 point was added for each run scored.

Additionally, batsmen should get points for certain challenging milestones. In cricket, a batsman performs well when he/she has reached 50 and 100 runs (half-century and full-century, respectively) in an innings. Thus, 2 points were added for every half-century, and 8 points were added for every century.

There is also the matter of how quickly the batsman scored their runs. For example, 50 runs being scored off just 20 balls is much more impactful than 50 runs off 50 balls, since more

of the game is still playable. Strike rate is a metric that can measure this, otherwise defined as dividing the number of runs taken by the number of balls consumed by the batsman and multiplying it by 100. So in our example, batsman 1 would have a strike rate of 250, whereas batsman 2 would have a strike rate of 100. Points were added if the strike rate was above 180, 150, and 120.

Additionally, if the strike rate and the runs were high for a batsman, those runs would be more impactful. For example, 30 runs off 15 balls is harder and thus more impactful than 10 runs off 5 balls. Thus, a multiplier was added to the strike rate score at certain marks. If 0-10 runs were scored, a multiplier of 0 was added, negating the strike rate score completely. This was because few runs were scored due to the innings ending or the batsman getting out, so the strike rate would not have mattered too much. If 10-25 runs were scored, a multiplier of 1 was added. Finally, if 25+ runs were scored, a multiplier of 2 was added.

Fours and sixes also needed to be rewarded, considering they can tilt the favor towards the batting side. Originally, players would get 1 additional point for every four and 3 additional points for every six.

For bowlers, the most important thing is wickets (or outs). Once a wicket is taken, a partnership between two batsmen is broken, and a new batsman must come in. Typically, this disrupts the rhythm and flow of the batsmen. Thus, it makes sense that as a bowler accumulates more and more wickets, they are disrupting the batsmen more and more. Then, as the bowlers took more wickets, they should get more points per wicket. Originally, bowlers were awarded 12 points for their 1st wicket, 16 for their 2nd, 20 for their 3rd, and so on.

The next most important thing is not giving up so many runs in their overs. Each bowler is allowed to bowl 4 overs (24 balls). The way to measure this is called economy. The economy for a bowler is essentially the average number of runs they concede in an over. The way to calculate this would be to take the number of runs conceded, divide it by the total number of balls bowled, and multiply by 6 to get the average runs per 6 balls (or an over). For example, someone who bowled 2 overs and conceded 10 runs would have an economy rate of 5.00, whereas someone who bowled 1.3 overs (9 balls) and conceded 10 runs would have an economy rate of 6.67. Essentially, the lower the economy rate, the better the bowler is bowling. Originally, if the economy was under 6.0, bowlers were awarded 18 points, 6.0-6.5 would yield 15 points, 6.5-7.0 would yield 12 points, 7.0-7.5 would yield 9 points, 7.5-8.0 would yield 6 points, and finally, 8.0-9.0 would yield 3 points.

Then there are dot balls. These are balls in which the batsman does not get any runs. Since T20 cricket only has 120 balls played, each dot ball is critical in helping the bowler's side. Dot balls also help decrease the economy for a bowler. Originally, in every dot ball bowled, the bowler was awarded 2.5 points.

Finally, it's clear that bowlers who bowl more overs are typically better than those who bowl less, so it would make sense to give some points to the total overs bowled. However, not many points were awarded for this, as overs bowled does not show the full picture of who is doing the best in the match. It is entirely possible that a bowler completely slips up in their final

over and gets hit for many runs. Thus, 2.5 points were awarded to those who completed their full 4 overs, 2 points to those in between 3 and 4 overs, 1.5 points to those in between 2 and 3 overs, 1 point to those in between 1 and 2 overs, and 0.5 points to those in between 0 and 1 over.

4 Changes

As I kept running the program, I wasn't pleased sometimes with how the results turned out. Sometimes there would be too many batsmen in the top 11, and I had to increase the bowling points. Other times, I noticed that there were too many pace bowlers and not as many spin bowlers, and I had to add a new metric. There were also times when there were too many allrounders, and I had to increase the extremities of the point values. Along with this, there were sometimes bugs in the code that wouldn't allow a certain metric to be run correctly. The changes I highlighted below only show a few changes made, and a full list of the scoring metrics can be found below. Most of the changes not mentioned involved adding more subcategories for each metric and increasing overall point totals.

It came to my attention that in T20 cricket, not many half-centuries or centuries are scored. Thus, I needed to bolster the points for reaching those milestones, as well as add another mark of 30 runs. For 30 runs, 7 points were added. For 50 runs, or a half-century, 18 points were added. Finally, for 100 runs, or a century, 43 points were added. Centuries in T20 cricket are extremely rare; in fact, only 12 centuries were recorded in this installment of the IPL. That is why so many points were added when a century was scored.



Fig 1: Why each boundary matters

For 4s and 6s, I wanted to find just how much more a 6 impacts a game than a 4. As stated by ESPNcricinfo, fours boost odds by 1.89, whereas sixes boost odds by 2.89. Thus, I made sure sixes were $2.89/1.89 = 1.53$ times more powerful than fours, which is much less than the 3 times more powerful I had before.

At this point, a lot more spin bowlers were showing up in the top 11 over their pace bowler counterparts. This was likely because spin bowlers are meant to slow the game down in the middle overs, and likely have a higher economy over the pace bowlers. Pace bowlers conceded more runs but made up for it in the wickets they got. Thus, a bowling average was introduced, which divides the total number of runs conceded by the number of wickets taken. An average under 20 would yield 20 points, under 23 would yield 14 points, under 26 would yield 8 points, under 30 would yield 5 points, and under 35 would yield 2 points.

Wickets to batsmen were also added, as well as not-outs. If a batsman is out in a way that is likely their fault, more points are deducted. If a batsman was not out, however, no points were

deducted. The wickets to the bowlers changed in that I added an exponential so successive wickets are worth more.

Finally, fielding was added, since good fielders allow fewer runs to be scored. Even though stats don't show the full picture with fielding like the difficulty of a catch or saving runs, I still gave points for certain marks. I manually entered all the fielding data from catching, stumping, run-outs via a thrower and a catcher, and run-outs via a direct hit into a spreadsheet converted to a data frame. The point values can be found in section 1.4.

5 Final Metric Numbers

5.1 Batsmen

- Runs
 - Every Run = 1.03 Points
 - Every 4 = $1.89 * 1.03 = 1.9467$ Points
 - Every 6 = $2.89 * 1.03 = 2.9767$ Points
 - 30+ Runs = 7 points
 - 50+ Runs = 18 points
 - 100+ Runs = 43 points
- Out
 - LBW/Bowled = -4 points
 - Stumped = -6 points
 - Hit wicket = -7 points
 - Runout = -8 points
 - Retired out = -4 points
 - Caught/Caught+Bowled = -1.5 points
 - Retired hurt = -0.5 points
 - Not out = 0 points
- Strike Rate
 - 300+ = $20 * 1.8 = 38$ points
 - 250-300 = $15 * 1.75 = 26.25$ points
 - 225-250 = $13.5 * 1.7 = 22.95$ points
 - 210-225 = $12 * 1.65 = 19.8$ points
 - 200-210 = $10 * 1.6 = 16$ points
 - 180-200 = $8 * 1.6 = 12.8$ points
 - 170-180 = $7 * 1.5 = 10.5$ points
 - 160-170 = $6 * 1.5 = 9$ points
 - 150-160 = $4.5 * 1.5 = 6.75$ points
 - 130-150 = $3 * 1.4 = 4.2$ points
 - 120-130 = $1.5 * 1.4 = 2.1$ points
- Multipliers for Strike Rate
 - 0-15 Runs = 0x
 - 15-20 Runs = 1x

- 20-30 Runs = 1.5x
- 30-50 Runs = 2.5x
- 50-80 Runs = 4x
- 80+ Runs = 5x

5.2 Bowlers

- Every Dot = 4 points
- Wickets: $17 + n^2$ points, where n is the nth wicket
 - 1st Wicket = $17+1 = 18$ points
 - 2nd Wicket = $17+4 = 21$ points
 - 3rd Wicket = $17+9 = 26$ points
 - 4th Wicket = $17+16 = 33$ points
 - 5th Wicket = $17+25 = 42$ points
 - 6th Wicket = $17+36 = 53$ points and so on.
- Extras that are the bowler's fault
 - Every wide: -0.75 points
 - Every no-ball = -3 points
- Economy
 - Under 5.00: 29 points
 - 5.00-5.50: 23 points
 - 5.50-6.00: 18 points
 - 6.00-6.50: 14 points
 - 6.50-7.00: 10 points
 - 7.00-7.50: 7 points
 - 7.50-8.00: 5 points
 - 8.00-9.00: 3 points
 - 9.00-10.00: 1 points
 - 10.00-12.00: -1 points
 - 12.00-13.00: -3 points
 - 13.00-14.00: -5 points
 - 14.00+: -6 points
- Bowling Average
 - Under 20.00: 20 points
 - 20.00-23.00: 14 points
 - 23.00-26.00: 8 points
 - 26.00-30.00: 5 points
 - 30.00-35.00: 2 points
 - 35.00+: 0 points
- Overs Bowled
 - 4.0 overs: 4 points
 - 3.0-3.5 overs: 2 points

- 2.0-2.5 overs: 1.5 points
- 1.0-1.5 overs: 1 points
- 0-0.5 overs: 0.5 points
- 0 overs: 0 points

5.3 Fielders

- Catch: 7 points
- Stumping: 16 points
- Runout Thrower (if 2 players involved): 9 points
- Runout Catcher (if 2 players involved): 8 points
- Runout Direct Hit (1 player involved): 12 points

6 Results

6.1 Dream Team

rank	player	role	batting style	bowling style	team	total_score
1	Shubman Gill	Batsman	Right-hand Bat, Opener		GT	112.0559176
2	YBK Jaiswal	Batsman	Left-hand Bat, Opener		RR	104.0728786
3	AR Patel	Bowling Allrounder	Left-hand Bat	Slow Left arm Orthodox	DC	102.7533
4	F du Plessis	Batsman	Right-hand Bat, Middle Order		RCB	102.1402286
5	Rashid Khan	Bowling Allrounder	Right-hand Bat	Legbreak Googly	GT	101.8071
6	H Klaasen	Wicket-Keeper	Right-hand Bat		SRH	100.1979
7	C Green	Batting Allrounder	Right-hand Bat	Right arm Fast medium	MI	99.3744
8	MM Sharma	Bowler		Right arm Medium	GT	99.16071429
9	SA Yadav	Batsman	Right-hand Bat		MI	95.93488125
10	Mohammed Shami	Bowler		Right arm Fast	GT	95.09392353
11	Naveen-ul-Haq	Bowler		Right arm Medium fast	LSG	94.30334286
12	RA Jadeja	Allrounder	Left-hand Bat	Slow Left arm	CSK	93.419

				Orthodox		
13	Mohammed Siraj	Bowler		Right arm Fast	RCB	93.28785714
14	V Kohli	Batsman	Right-hand Bat, Top Order		RCB	93.27733571
15	M Pathirana	Bowler		Right arm Fast	CSK	92.6875

Table 1: The table above shows the top 15 individuals and their stats in the IPL 2023. These people will represent “the squad” or the selection pool for the starting XI.

As seen in the table, the most valuable player in the IPL 2023 was Shubman Gill, which matches up with the IPL's MVP award. Making a starting XI from the data proves to be more challenging. The IPL only allows 4 foreign players in the starting 11; since 5 foreign players are in the top 11, changes must be made.

Since Naveen-ul-Haq is the lowest-ranked foreign player, it would make sense to replace him. Without Naveen, the team is left with 5 players who can bowl. In a T20 game, every bowler can bowl a maximum of 4 overs, so in this case, everyone would need to bowl 4 overs. This is not ideal if someone is not having a good day with the ball. Thus, another bowler is necessary. The next option would be RA Jadeja bats and bowls the same as AR Patel. In most cases in the IPL, another spinner in the form of RA Jadeja might be unnecessary. Therefore, Mohammed Siraj should be selected in the starting XI.

There is also the fact that the IPL 2023 allows substitutes during the match, who are called impact players. Only 1 substitution can be made per game. In that case, depending on the match, it might be beneficial to substitute RA Jadeja or V Kohli, as an extra batting unit.

Thus, the starting XI would be YBK Jaiswal, Shubman Gill, F du Plessis (c), C Green, SA Yadav, H Klaasen (wk), Rashid Khan, AR Patel, Mohammed Shami, Mohammed Siraj, MM Sharma, with possible impact players being RA Jadeja, V Kohli, Naveen-ul-Haq, and M Pathirana.

6.2 Team Analysis

Out of the 11 players in a cricket match, usually around the 4-5 best players contribute to 80% of the team's winnings. Because of this, a team needs to have around 4-5 outstanding players if they want to win matches.

One method to assess the quality of teams would be to examine players' ranks to see which team has the lowest sum of the top 5 ranks. This method of scoring used in high school cross country emphasizes placement more than the actual score but is useful in noting differences between ranks.

However, this excludes the fact that differences in some ranks could be very minute, whereas others could be drastic. Another way would be to look at the top 5 players' scores and add them to see each team's placement.

Method 1						
GT	560.3722045					
RCB	444.4412786					
MI	432.6789006					
CSK	424.2999217					
RR	411.256664					
DC	398.3758883					
LSG	391.2693844					
KKR	361.9467384					
PBKS	347.9141164					
SRH	347.7965196					
Method 2						
GT	1	5	8	10	23	47
RCB	4	13	14	19	46	96
MI	7	9	17	25	41	99
CSK	12	15	18	24	34	103
RR	2	16	30	35	47	130
DC	3	21	32	33	57	146
LSG	11	28	31	37	44	151
KKR	26	29	36	38	66	195
PBKS	22	45	55	62	63	247
SRH	6	20	80	84	88	278

Fig 2: Team Rankings

In the end, both ways yield the same team ranking: GT, RCB, MI, CSK, RR, DC, LSG, KKR, PBKS, and finally SRH. The actual group rankings ended up being GT, CSK, LSG, MI, RR, RCB, KKR, PBKS, DC, and SRH, with the top 4 advancing to the playoffs. The playoff rankings were CSK, GT, MI, and LSG.

So how did CSK become 1st, when according to the rankings, they should be 4th? And how did RCB end up not even making the playoffs, when clearly (according to the rankings), they have a strong team?

To answer the latter, RCB only missed making the playoffs by 1 game out of the 14. This can happen due to bad luck, but RCB also had several problems. According to Times Now News, "RCB scored a total of 2502 runs, out of which a staggering 71% (1769) came from Kohli, Maxwell, and Faf" (Kataria). The team relied too much on just 3 players for batting and only Siraj for bowling. This reliance on ultra-strong players made the rest of the domestic players on the team weaker and caused the team to miss out on the playoffs.

CSK had a different path than RCB. Even though the individuals on the team aren't as strong as GT's, their team spirit was one of the best in the league. MS Dhoni, their captain, did not play too well in the season, as his total score of 22.79 was the 6th lowest out of all 134 players who played at least 6 matches. Even so, his experience from captaining India to a World Cup win in 2011 and captaining CSK to 4 wins before this season meant he was one of the best

captains in the sport of cricket. CSK with their wholesome team and coaching were able to train players to become the best versions they could be, and led to them winning their knockout games and the tournament.

6.3 Most Underpaid Players

For context into currency below, 1 lakh INR = 100,000 INR, and 1 crore INR = 10,000,000 INR. At the time of publication, \$1 USD is about 83.75 INR.

In the IPL 2023, the average cost per point was 8.69 lakhs. I wanted to try to minimize this by finding the most underpaid players and selecting a team of them. To determine the most underpaid players, I looked at the auction prices the players were bought. Additional research on unsold players who were sold later on was done as well. I ordered all the auction prices from highest to lowest and gave each player an auction price based on their total score. For example, the highest auction price was 1850 lakhs for SM Curran, and the 2nd highest was 1750 lakhs for C Green. Now, those prices would be what the #1 and #2 players by the total score system should have been bought at. This is what I call "price off rank". So Shubman Gill would have a price off rank of 1850 lakhs since he was the #1 player by total score, and YBK Jaiswal would have a price off rank of 1750 lakhs since he was the #2 player by total score.

player	price off rank	price (lakhs)	difference	rank
MM Sharma	1525	50	1475	8
Naveen-ul-Haq	1500	50	1450	11
YBK Jaiswal	1750	400	1350	2
M Pathirana	1200	20	1180	15
Akash Madhwal	1200	20	1180	17
H Klaasen	1600	525	1075	6
Shubman Gill	1850	800	1050	1
DP Conway	1150	100	1050	18
B Sai Sudharsan	1000	20	980	23
PP Chawla	1000	50	950	25

Table 2: The top 10 underpaid players

In this list, many pace bowlers like MM Sharma, Naveen-ul-Haq, M Pathirana, and Akash Madhwal showed up. Additionally, the 2 young top-ranked players Shubman Gill and YBK Jaiswal made the top 10 as well, despite having slightly higher prices than the others.

6.4 Budget Team

Normally in the IPL, teams have 95 crores (or a little over 11 million USD) to select a team. The budget team that will be assembled will cost only 25 crores (a little less than 3 million

USD). This team would need 3 solid pace bowlers, 2 spin bowlers, 4-5 pure batsmen including a wicketkeeper, and 1-2 allrounders. For the 3 pace bowlers, MM Sharma, Naveen-ul-Haq, and M Pathirana would be perfect, since they were bought at only 50, 50, and 20 lakhs respectively. For spin bowlers, PP Chawla (a right-arm spin bowling all-rounder) and M Markande (left-arm leg break spin bowler) each at 50 lakhs would be the best options, since better spin bowlers were bought at least 1200 lakhs. For batsmen, Shubman Gill and YBK Jaiswal are musts, considering the saved money along with the fact that their 112 and 104 score points per game, respectively, tower over everyone else's points. Gill and Jaiswal were bought at 800 and 400 lakhs, respectively.

Additionally, B Sai Sudharsan would be perfect on this list, being bought at just 20 lakhs. That brings the total cost up to 1440 lakhs, so 1060 lakhs are left. For a wicketkeeper, it is impossible not to choose H Klaasen, considering his score of 100, compared to the other wicket-keepers at 85, 68, 67, 59, and so on. H Klaasen would cost 525 lakhs, so only 535 lakhs are left for the last 2 players. Of the rest, DP Conway (also a wicket-keeper with 85 points) and KR Mayers (batting allrounder with 75 points) who cost 150 lakhs in total would be the best of whoever is left. However, since Conway is a wicketkeeper, and there are 385 lakhs left, it is possible to trade Klaasen out for someone else with a higher score. The option for this would be F du Plessis, with a score of 102. This trade would cost $700 - 525 = 175$ lakhs. With only 210 lakhs left, reserves for the team could be bought (not covered here).

All in all, the starting team would be YBK Jaiswal, Shubman Gill, F du Plessis (c), B Sai Sudharsan, DP Conway (wk), KR Mayers, PP Chawla, M Pathirana, Naveen-ul-Haq, M Markande, and MM Sharma. This budget team would cost 2290 lakhs, and yield a score of 925.76 points. This would mean every point on this team would cost 2.47 lakhs, which is much less than the average of everyone at 8.69 lakhs.

6.5 Best Performances

To look at the best performances in the IPL 2023, the scores from each match would need to be printed and then ranked. The best performance came from Rashid Khan's all-around supremacy in match #57 in GT vs MI. His 4 wickets with an economy rate of only 7.50 in a high-scoring match and his knock of 79 off 32 in the same game made him achieve the highest score of the whole season at 379.79 points. The 2nd best performance came in match #69 from Cameron Green batting 100* off 47 and bowling only 2 runs in 1 over, giving him 336.39 points. The 3rd best came from Shubman Gill's 129 runs off 60 in match #73 with 334.76 points, 4th best from Yashasvi Jaiswal's 124 runs off 62 balls in match #42 with 332.18 points, and the 5th best performance came from Suryakumar Yadav's 103* off 49 in match #57 with 305.37 points.

6.6 MVP

By going through the catalog of each game in what was used to get the best performances, it's also possible to find the best performer, or MVP, of each match. Then, a comparison between the best performer from the model and the MVP of the match can be made.

In the IPL, the MVP is typically awarded to a player on the winning team, even if a player on the losing team contributed a lot more. Thus, to predict the MVP in the IPL, the player with the largest contribution to the winning team was chosen.

I also wanted to see if the model matched the ESPNcricinfo impact model reasonably. Since the ESPNcricinfo impact model shows the most impactful player, regardless of the match's outcome, the highest contributor by total score in my model was compared to the most impactful player in ESPNcricinfo.

Even so, if the player who contributed the most according to my model and ESPNcricinfo was on the losing team and ended up winning MVP in the IPL just because of pure skill, I counted it as a success. This is seen in matches 22, 40, 41, and 42.

Match	MVP by Team	IFL MVP	Same?	MVP by Score	Cronds MVP	Same?
1	Shubman Gill	Rashid Khan		RD Gaidwad	RD Gaidwad	1
2	Anshdeep Singh	Anshdeep Singh		1 Anshdeep Singh	Anshdeep Singh	2
3	MA Wood	MA Wood		1 MA Wood	KK Mayers	2
4	JC Butcher	JC Butcher		1 JC Butcher	JC Butcher	1
5	V Kohli	F du Plessis		2 Virat Kohli	Virat Kohli	1
6	MSH Ai	MSH Ai		1 KR Mayers	MSH Ai	2
7	Mohammed Shami	S Sai Sudhansan		2 Mohammed Shami	Mohammed Shami	1
8	S Dhawan	NT Ellis		2 S Dhawan	NT Ellis	2
9	SN Thakur	SN Thakur		1 SN Thakur	SN Thakur	1
10	KH Pandya	KH Pandya		1 KH Pandya	KH Pandya	1
11	YBK Jaiswal	YBK Jaiswal		1 YBK Jaiswal	YBK Jaiswal	1
12	AM Rahane	RA Jadeja		2 AM Rahane	AM Rahane	1
13	VR Iyer	RK Singh		2 VR Iyer	VR Iyer	1
14	S Dhawan	S Dhawan		1 S Dhawan	S Dhawan	1
15	N Pooran	N Pooran		1 N Pooran	Mohammed Siraj	2
16	JP Bhavendralal	RG Sharma		2 AR Patel	AR Patel	1
17	R Ashwin	R Ashwin		1 RA Jadeja	RA Jadeja	1
18	MM Sharma	MM Sharma		2 MM Sharma	Shubman Gill	1
19	HC Brook	HC Brook		1 HC Brook	HC Brook	1
20	Mohammed Siraj	V Kohli		2 Mohammed Siraj	Kuldeep Yadav	2
21	Sikandar Raza	Sikandar Raza		1 Sikandar Raza	Sikandar Raza	1
22	Ishan Kishan	VR Iyer		1 VR Iyer	VR Iyer	1
23	SD Haldnyer	SD Haldnyer		1 SD Haldnyer	Mohammed Shami	2
24	DP Conway	DP Conway		1 GJ Maxwell	GJ Maxwell	1
25	C Green	C Green		1 C Green	C Green	1
26	Avesh Khan	MP Stoinis		2 Avesh Khan	Avesh Khan	1
27	Mohammed Siraj	Mohammed Siraj		1 Mohammed Siraj	Mohammed Siraj	1
28	AR Patel	I Sharma		2 AR Patel	DA Warner	2
29	DP Conway	RA Jadeja		2 DP Conway	DP Conway	1
30	MM Sharma	MM Sharma		1 KH Pandya	HH Pandya	2
31	Anshdeep Singh	SM Curran		2 C Green	C Green	1
32	GJ Maxwell	GJ Maxwell		1 GJ Maxwell	GJ Maxwell	1
33	AM Rahane	AM Rahane		1 AM Rahane	AM Rahane	1
34	AR Patel	AR Patel		1 B Kumar	AR Patel	2
35	Shubman Gill	A Manohar		2 Shubman Gill	Shubman Gill	1
36	JJ Roy	Cv Varun		2 JJ Roy	PWN de Silva	2
37	YBK Jaiswal	YBK Jaiswal		1 YBK Jaiswal	YBK Jaiswal	1
38	KR Mayers	MP Stoinis		2 KR Mayers	KR Mayers	1
39	V Shankar	J Little		2 Rammanullah Gurto	Rammanullah Gurto	1
40	AMRishabh Sharma	MR Marsh		1 MR Marsh	MR Marsh	1

41	JM Sharma	DP Conway	1	DP Conway	DP Conway	1
42	TH David	YBK Jaiswal	1	YBK Jaiswal	YBK Jaiswal	1
43	JR Holder	F du Plessis	0	JR Holder	K Godtham	0
44	Muhammad Shami	Muhammad Shami	1	Muhammad Shami	Muhammad Shami	1
45	No Result	NA	0	No Result	NA	0
46	Ishan Kishan	Ishan Kishan	1	Ishan Kishan	SA Yadav	0
47	AJ Russell	Cv Varun	0	T Natarajan	SH Thakur	0
48	Raheem Khan	Raheem Khan	1	Raheem Khan	HR Pandya	0
49	M Pathirana	M Pathirana	1	M Pathirana	N Wadhwa	0
50	FD Salt	FD Salt	1	FD Salt	FD Salt	1
51	Shubman Gill	Shubman Gill	1	Shubman Gill	WP Saha	0
52	Ashutosh Sharma	GD Phillips	0	JC Butler	YS Chahal	0
53	N Rana	AD Russell	0	N Rana	Cv Varun	0
54	SA Yadav	SA Yadav	1	SA Yadav	SA Yadav	1
55	RA Jadeja	RA Jadeja	1	AR Patel	AR Patel	1
56	YBK Jaiswal	YBK Jaiswal	1	YBK Jaiswal	YBK Jaiswal	1
57	SA Yadav	SA Yadav	1	Raheem Khan	Raheem Khan	1
58	N Pooran	PH Mankad	0	N Pooran	KH Pandya	0
59	P Srinan Singh	P Srinan Singh	1	P Srinan Singh	P Srinan Singh	1
60	GJ Maxwell	WD Parnell	0	GJ Maxwell	WD Parnell	0
61	SP Narine	RK Singh	0	SP Narine	DL Chahal	0
62	Shubman Gill	Shubman Gill	1	B Kumar	Shubman Gill	0
63	MP Stoinis	MP Stoinis	1	MP Stoinis	MP Stoinis	1
64	RR Rossouw	RR Rossouw	1	RR Rossouw	RR Rossouw	1
65	V Kohli	V Kohli	1	H Klaassen	H Klaassen	1
66	D Pathak	D Pathak	1	SM Curran	SM Curran	1
67	DP Conway	RD Gakwad	0	DP Conway	DP Conway	1
68	N Pooran	N Pooran	1	RK Singh	RK Singh	1
69	C Green	C Green	1	C Green	C Green	1
70	Shubman Gill	Shubman Gill	1	Shubman Gill	Shubman Gill	1
71	RA Jadeja	RD Gakwad	0	RA Jadeja	RA Jadeja	1
72	Aakash Madhwal	Aakash Madhwal	1	Aakash Madhwal	Aakash Madhwal	1
73	Shubman Gill	Shubman Gill	1	Shubman Gill	Shubman Gill	1
74	DP Conway	DP Conway	1	B Sai Sudharsan	B Sai Sudharsan	1

Fig 3: MVP Analysis

Of these 74 matches, my model matched up with the IPL MVP in 47 of the games, and with the espnricinfo MVP in 51. That is a 64% and 70% accuracy rate, respectively. Even in the games where the model was unable to select the player with the award, it was often very close, picking the 2nd or 3rd best options in most of the cases.

7 Conclusion

This paper covered how sabermetrics were used to open up the sport of cricket. Using a scoring system similar to fantasy cricket, along with adding tweaks here and there, a model was created. This model was used to create a dream team, along with looking at other statistics like MVP, a budget team, best individual performances, underpaid players, and an overall team analysis.

It is important to mention the limitations of this whole analysis. For batsmen, the nature of how important the runs were can't be analyzed through the approach here. For example, for RK Singh's 5 sixes to win the KKR vs GT match in the final over, the model can only notice that 5 sixes were hit, not the game-changing importance of it. For fielders, not every catch is the same. Some catches would have taken a valiant effort to get to the ball and save it, whereas others are simple drops. For bowlers, the model doesn't consider when exactly the bowler was played. It is much easier to hit balls for boundaries in the powerplay when compared to the middle overs.

Even so, my model explains a lot of how and why certain cricketers created an impact.

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The Growing STEM Crisis and its Eminent Threat to the Superpower Status of the United States By Anshuman Roy

Abstract

The STEM(*Science, Technology, Math, and Engineering*) crisis is an event that is currently happening within the United States of America, in which there are an inadequate number of STEM jobs being filled. More prepared, and STEM-oriented countries are taking over important roles in technology and other sciences. In this review, we will dive deep into the STEM Crisis, and assess the causes, impacts, and plausible solutions there are towards this issue.

Introduction

The United States of America must find a solution to the rapidly growing STEM shortage, or its superpower status is at immense risk. The USA has fallen drastically behind in STEM(*Science, Technology, Math, and Engineering*) since the 1980s, compared to global competitors such as China and Russia. Causes for this profound STEM crisis has originated from the lack of educated STEM professionals in America, to spread information. The crisis has been increasingly eminent in lower-class areas of the USA, without adequate funding and resources. It began developing in the 1980s, as Americans were losing interest in STEM education, a consequence of the ending of the space race, an event that infused STEM with American national pride. As a result, the STEM crisis is correlated to numerous other issues, including STEM education gradually fading from the foundations of American education. The significance of this, with the emergence of AI and cyber-related threats, is that the workforce in the United States must be prepared, or will be at substantial risk, looking to be overtaken by more prepared alternatives, including China. Overall, the STEM crisis, a significant problem in the United States of America, has been caused by a lack of qualified officials in the STEM field residing in the US, threatening interest and proficiency across the nation. This gives power to other global competitors. Organizations such as Project Lead The Way and the Cognizant Foundation are carrying out plausible solutions to this issue.

Causes of STEM Crisis

Primarily, the STEM crisis has been occurring due to numerous causes, including the lack of qualified professionals and STEM education provided in the primary stages of schooling, weakening the foundations to cultivate talent. The United States has become increasingly reliant on offshoring to fill STEM job opportunities, compared to professionals being developed through the American education system. This issue has gradually worsened over time, as the lack of qualified STEM professionals in previous generations has affected current generations, especially, as US qualified STEM professionals have drastically reduced. This all occurred due to the necessity to fill jobs in the STEM workforce, in which Americans lacked adequate training. Secondly, lack of STEM interest has been a prevalent issue, with children struggling to find passion in STEM-related topics introduced in the schooling system. STEM interest in the

US peaked during the Cold War, for a multitude of reasons, including the space race, which enhanced Americans' interest in STEM, for numerous job opportunities were required by companies such as NASA. However, without a major event to spark STEM interest, exposure to these topics has been declining. Moreover, factors such as gender, and racial disparities, efficient time spent in school, as well as the COVID-19 pandemic, have reduced STEM talent from thriving in the US, some being more recent factors. According to a recent report, the lack of introduction to newer STEM topics in the schooling system, such as AI and Data Science, which are dominating today's industry, are primary factors in the lack of STEM proficiency across the United States(Schneider). Additionally, according to The Hill, "If more young people, motivated by STEM, understood the impact of operations research and analytics, and more people in academia could advise them about meaningful and rewarding career paths in this incredible field, there's little doubt these students would eagerly seek out operations research and analytics programs, as well as careers in science and technology"(Albert Gertsman). These excerpts of evidence are essential as they highlight the lack of STEM motivation and opportunities available for children of younger ages. This lack of immediate exposure may ultimately result in a decline of interest in STEM, as children continue to grow older. Following the evidence, STEM interest must be generated quickly, as exposure and quality material are necessary at younger ages for the United States to remain globally competitive. New topics are not being introduced, showing a lack of preparation. This is related to the lack of preparation, since young people are unable to comprehend the importance of STEM, not discovering both interest and understanding. The lack of understanding of STEM in younger stages of schooling has resulted in a declining level of quality in the US. Global competitors who cultivate STEM talent and interest at a young age, such as China, dominate the industry. According to the World Population Review, students from China and Taiwan attend at least 9.5 hours of schooling per day, highlighting the rigorous academic foundations that are developed at a young age(Average School Day Length by Country 2024). Furthermore, according to EBSCO, "Right now, we continue to slip behind because our immigration system doesn't promote highly-skilled workers in science, technology, manufacturing, and engineering by giving them a pathway to stay and contribute to the U.S. after they receive an education"(Rao). These pieces of text demonstrate how the immigration system is a major cause of the STEM crisis in the USA. According to the evidence, students from China and Taiwan attend schooling at least 9.5 hours per day on average, highlighting the strong academic culture in those countries. However, the US immigration system doesn't promote holding these highly skilled workers from other countries, with prior experience and knowledge, for the benefit of the US. This is a prevalent issue, as those highly skilled workers attending American universities have valuable assets that could be passed down to future generations, including qualified STEM education. Thus, these are the various causes of the STEM crisis in the United States of America, which have resulted in numerous negative impacts threatening the superpower status of the nation.

Impacts of STEM Crisis

Consequently, as a result of the causes of the STEM crisis, American students have been demonstrating a lack of proficiency in numerous topics, as well as racial and gender disparities in the field, all resulting in numerous open job opportunities, without sufficient skilled workers. This issue impacts numerous US-based STEM companies, as a shortage of skilled workers has resulted in offshoring, as a more cost-efficient solution. However, as this issue continues to grow, STEM qualification is required, and offshoring is not providing enough skilled workers for the necessities of AI, Data Science, Security, and more. The STEM crisis has progressively gotten worse over time, highlighted by Americans pursuing more visual arts careers in comparison to STEM. Moreover, events including the pandemic and more since 2020 affected companies, resulting in increased job loss. Overall, this has had a detrimental impact on the US economy, due to STEM power shifting to global competitors, reducing the control that the USA previously had in the field. Due to the lack of quality time being spent on STEM, the US is now at risk of being more vulnerable and unprepared, with less control over growing industries. According to a 2019 Mathematical survey, the US ranks 15th out of 64 countries in average math scores, with 21% of 12th graders proficient in mathematics, and 22% of 12th graders proficient in science, with proficiency decreasing as students continue to progress in academics(Athanasia). Additionally, according to the American Affairs Journal, “By 2009, for example, the total number of students in college had grown by more than 50 percent since 1985. But in mathematics and statistics, there were only 15,496 graduates in 2009, not much more than the 15,009 graduates in 1985. More students were studying the visual and performing arts than were studying computer science, math, and chemical engineering combined”(Herman). These excerpts of evidence are pivotal as they directly demonstrate the lack of STEM proficiency in children across the United States, with statistics compared to other countries. As stated by the first piece of evidence, the lack of STEM-directed education is causing American students to decline in math and science proficiency, directly resulting in an immediate decline in STEM interest. Due to the decline in interest, more Americans are choosing to pursue a career in the visual and performing arts, reducing the number of talented workers in the STEM field from the United States of America. Both of these pieces of evidence demonstrate how lack of qualified instruction is resulting in a chain of effects related to the STEM crisis, from lack of proficiency to reduced interest. The Cognizant Foundation states that according to a survey conducted by the National Association for Business Economics, over half of business survey respondents have a shortage of skilled workers, an increase of 10% from the previous quarter, predicted to worsen over time. 3.5 million STEM-related jobs will need to be filled by 2025 (Beamer)). In addition, according to the 74, “Furthermore, the gaps in qualified applicants for STEM jobs are even more pronounced between genders and ethnicities, and while STEM jobs and degrees have steadily increased since 2000, the diversity of the workforce has not. The U.S. simply cannot compete in the global economy with so many Black, Hispanic, and female students not mastering needed STEM skills and aptitudes”(Schneider). These excerpts of evidence truly highlight the impact of the STEM crisis in the United States. This is due to the limit of qualified instruction in STEM that makes education in the field difficult to attain, especially in lower-class areas. Thus,

opportunities must be fairly provided to all students for the future STEM workforce composition to find interest and seek related opportunities. The STEM disparities correlate to the shortage of skilled workers, as people primarily living in affluent areas, have several advantages over their counterparts. This impact is detrimental, as STEM talent isn't being discovered, and cultivated across all communities. Thus, it is pivotal that STEM education is offered to people of different genders and ethnicities, otherwise STEM-related jobs will struggle to fill. In the final analysis, the impact of the STEM crisis is profound, however, there are numerous solutions to begin tackling this problem, and once again make the United States a global STEM powerhouse.

Solutions to STEM Crisis

Nevertheless, various solutions can gradually resolve the STEM crisis, including new bills causing reforms in education, tweaking the immigration system to allow for more talented individuals to reside in the country, addressing STEM inequality, and increasing preparation. Numerous companies and organizations have proposed to fix the difficulty by directing increased funding toward STEM education. However, these solutions have also been utilized to diversify the STEM field, directed towards underprivileged areas to increase STEM exposure. Many of these solutions have been put into place, such as the NEED Act, and the Supporting STEM Learning Act, providing funding for the access of high-quality STEM education, by helping ameliorate the STEM force of racial and gender inequalities. Additionally, another solution to the STEM crisis is allowing talented immigrants to reside in the US and spread STEM education, rather than temporarily traveling for higher education. As a result of this, offshoring will drastically reduce, with the number of skilled workers increasing with prepared immigrants, solidifying the superpower status of the USA. This act has been passed, referred to as the COMPETES Act, diversifying and increasing the longevity of the STEM field in the United States. According to EBSCO, passing the COMPETES Act would allow skilled immigrants to work for US businesses, cutting the STEM-related workforce by nearly a quarter, while simultaneously adding \$230 billion to the US economy. It would also provide future generations of America with qualified skilled professionals, for high-quality STEM education(Rao). Moreover, according to Congress, the 'Supporting STEM Learning Opportunities Act' — Provides grants to nonprofit programs that spread STEM education through extracurricular programs. Incorporate STEM principles in basic education, to enhance students' interest in the topic. Increased hands-on learning opportunities for people of different financial backgrounds, to increase the popularity of STEM(H.R.6521 — Supporting STEM Learning Opportunities Act). These two pieces of text introduce prominent solutions to the rapidly growing issue regarding the STEM crisis. This is because both of these solutions have longevity, fixing the STEM crisis at the root of its problem, compared to alternative solutions. This is because allowing immigrants with STEM experience to move into the United States will create a stronger STEM community. Furthermore, if this is fused with incorporating STEM principles through common schooling and extracurriculars, STEM interest will have the opportunity to increase in exposure, compared to its current situation. As a result, the economy will thrive, and

jobs in the STEM-related workforce will be filled. These improved finances could be used to further prepare students with a competitive education through extracurricular programs. According to the Cognizant Foundation, cultivating domestic talent is a key solution, and can be executed in numerous ways, such as creating charities and nonprofits to discover more diverse, and well-rounded STEM talent(Solving). Moreover, according to the American Affairs Journal, “One approach would be to designate certain STEM subjects, such as AI or additive manufacturing, as a “critical knowledge base” as described under the NDEA, and offer government scholarships and funding (including Department of Defense funding) that can be directed to those students and researchers working on that knowledge base”(Herman). These two pieces of evidence highlight that charities and nonprofits are key solutions to solving the STEM crisis, due to the advantage of inexpensive, hands-on learning for numerous American communities seeking aid. This same ideology can also be developed in the basic American schooling system, prioritizing newer STEM topics such as AI and providing funding and scholarships through this process. It can positively impact all genders, and races, reducing the disparity across the STEM field in the US, all a potential result of designating specific STEM talent and cultivating domestic talent through hands-on learning. Thus, it is a promising solution, and if enhanced with the talent of immigrants, STEM interest will thrive, and there will be fewer untaken jobs in the future. Thus, there are numerous solutions for the STEM crisis, which can gradually improve the declining situation in the American economy, currently being carried out by several organizations and nonprofits.

Organizations Raising STEM Awareness

Subsequently, due to the numerous solutions available for aiding the STEM crisis, various organizations are fighting against the issue of STEM disparities, proficiency, and the shortage of skilled workers, including Cognizant, and Project Lead The Way. These organizations are informing American citizens about the STEM crisis, raising awareness, and providing opportunities for inexpensive STEM learning, for all groups. Organizations including Project Lead The Way provide hands-on resources for children to gain interest, from simple robotics programs, all the way to computer science fundamentals. These are all solutions to the concern, rooting STEM interest in children at a young age, with a structured curriculum. Alternatively, organizations such as Cognizant Foundations are focusing on the present issue, and filling in open STEM jobs through funding different groups and promoting STEM to people of all races and genders. Both of these organizations are providing reliable solutions to the difficulty, instilling awareness and interest, critical in preserving the superpower status of the US in the STEM field. According to a comprehensive list of organizations that spread STEM education across the US, Project Lead the Way holds programs for school-age kids, as well as professional development, using hands-on STEM methods concerning solving real global issues. They also run programs such as PLTW Engineering and PLTW Computer Science, with 92% of PLTW students in high school showing an increased interest in STEM(Kamprad). Furthermore, “Code.org expands access to computer science and STEM education with an emphasis on

underrepresented groups. For example, Code.org's Hour of Code program possesses over 500 computer science activities for all ages and skill levels. Moreover, their CS Fundamentals program provides a full introductory computer science curriculum to classrooms in grades K-8" (Kamprad). These two excerpts of text highlight how STEM talent and equality have the potential to be dramatically increased. Project Lead the Way introduces STEM to children at young ages, and is an organization that is demonstrating the positive effect of early exposure, with 92% of high school PLTW having an increased interest in STEM. This is extremely beneficial, as with hands-on solutions being conducted, STEM interest will increase, and numerous other organizations will also carry out similar ideas. More filled jobs, as well as reliable STEM education for future generations, will be stable, with the prosperity of the current generation. Furthermore, organizations such as Code.org further diversify STEM interests across branches such as computer science, which will be increasingly beneficial in the future with the popularization of AI and Machine Learning. Both are organizations that enhance students to excel, by motivating them in a positive environment. The STEM Alliance is an organization obtaining grants to promote STEM education and professional development, while providing extracurricular activities at an accelerated pace, building a competitive environment (Creating a Network of STEM Learning Opportunities). Additionally, according to Cognizant Foundation, "Since its founding in 2018, the Cognizant Foundation has served historically excluded communities—and those who are underrepresented, underserved and underemployed—through the delivery of industry-relevant education, technical skills training programs and critical research needed to modernize the ways we educate and employ our workforce" (We envision a world where all communities can participate in and benefit from the digital economy). These two pieces of evidence demonstrate organizations that advocate for STEM education, while also providing professional development programs. Adults who were previously unexposed to STEM are being provided opportunities to gain experience, vital to resolve the current condition of the United States of America in STEM. These are highly rigorous, and competitive programs, absolutely indispensable for gaining quality experience to compete with other nations. To summarize, countless organizations are advocating for a thriving STEM education, hands-on, and inexpensive, to result in more skilled STEM workers, and close the gap formed since the 1980s.

Conclusion

To conclude, the STEM crisis has resulted in a lack of qualified officials in the STEM field residing in the US, decreased proficiency in STEM-correlated topics, and simultaneously threatened our workforce from thriving, shifting power to other global competitors. However, there are numerous solutions such as STEM-oriented funding, carried by organizations such as Project Lead The Way and the Cognizant Foundation. STEM proficiency rapidly declined in the US in the 1980s, caused by a lack of STEM exposure, reduced free educational opportunities taught by experienced professionals, and the foundations of STEM not being appropriately developed at early ages. These have had numerous negative impacts, including the rapid decline

of STEM interest and exposure. Providing funding to all communities, reducing disparities in the field, and constructing a competitive STEM environment in the foundations of American schooling will be necessary. By simply raising interest, incorporating STEM foundations in classrooms, and introducing newer topics available to large groups of people, solutions will continue to arise. The STEM field is growing with the emergence of topics including AI and Machine Learning, and the US must regain its competitive edge, for a lack of qualified officials in the workforce is putting its superpower status at immense risk.

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Virtual Reality in Rehabilitation: A Survey Analysis of Physical Therapists' Experiences

By Rishabh Katla and Abhiram Gogineni

Abstract

Millions of people across the world suffer with physical disabilities arising from various medical conditions or injuries. Physical therapy is often employed to help people regain their motor control. Recently, virtual reality (VR) has gained popularity as a form of rehabilitation in conjunction with regular physical therapy. This study aims to assess the effectiveness of VR as a form of rehabilitation for physical disabilities. Through the use of surveys sent out to physical therapists, data was collected in order to assess the effectiveness of VR. Out of all physical therapists contacted, most of them believe that virtual reality is an effective form of rehabilitation. Additionally, the majority of physical therapists believe that virtual reality has the potential to be widely used in the future as well. These findings clearly show that virtual reality has the potential to meet the needs of patients with physical disabilities. Through this research, more virtual reality systems should be developed for patients in physical therapy. As time progresses, virtual reality can have numerous applications and benefits in other sectors of medicine.

Introduction

A physical disability is a medical condition that inhibits one's ability to perform a physical activity in everyday life. Examples of physical activities can include walking, running, climbing stairs, or lifting^[1]. The United Nations estimate that about 1 billion people around the world live with some form of physical disability^[2]. Physical disabilities can result from conditions such as traumatic brain injury (TBI), stroke, spinal cord injuries, or cerebral vascular accident (CVA), just to name a few. Individuals with physical disabilities resulting from these conditions go through physical therapy to regain their motor control. Physical therapy involves certain exercises to improve mobility, massages to relieve muscle soreness, and treatments that use physical stimuli (electrotherapy, heat therapy, or cold therapy)^[3]. Virtual reality (VR) is an emerging technology that can be used by physical therapists to help patients regain their mobility and coordination.

Virtual reality can be defined as when individuals are placed in a computer-simulation and perform various tasks in a lifelike experience^[4]. In the early 1990s the use of virtual reality in physical therapy and rehabilitation skyrocketed^[5]. Over the past few years VR has played a significant role in the rehabilitation process of patients for both intellectual and physical disabilities. This study will be focused on virtual reality being used to treat physical disabilities only.

Two of the many medical conditions that have been addressed by virtual reality are stroke and chronic pain^[4]. Patients recovering from these conditions experience symptoms related to back or neck problems, and difficulty in walking, sitting, or bending over^[6,7]. Various virtual reality systems have the potential to mitigate the negative effects of these symptoms when used

accordingly by a physical therapist. Some examples of virtual reality systems which have been a success include REAL by Pneumbra, XR Therapy System by NeuroRehab, and Corpus VR [8,9,10].

Many previous studies have focused on the applications of virtual reality in treating stroke patients. There have been relatively few studies in which physical therapists assess the effectiveness of virtual reality as a form of rehabilitation. This study employs a survey that was given to physical therapists with experience in VR to obtain data on how effective VR can be as a rehabilitation method to treat physical disabilities. This study hopes to show the potential of VR as a form of rehabilitation for patients with physical disabilities.

Methodology

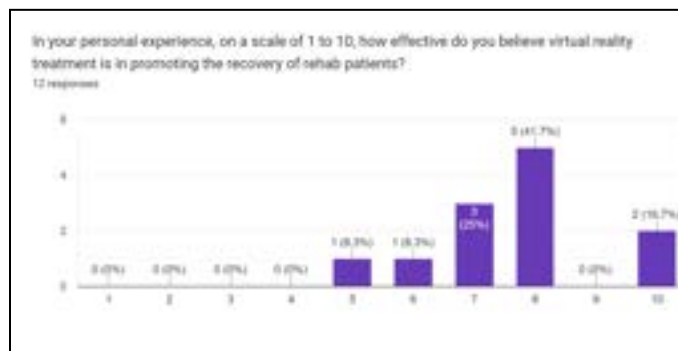
It is ambiguous to what extent physical therapists view virtual reality as an effective form of rehabilitation to treat patients with physical disabilities. In order to fill in this gap, an extensive amount of qualitative and quantitative data from physical therapists is necessary. Surveys were chosen as the form of data collection for this study because they minimize the time that is needed to get data, allows for easier interpretation of data, and it is convenient for the physical therapist to provide data.

The survey included six questions (two multiple-choice questions and four rating-scale questions) which asked physical therapists to assess the effectiveness of virtual reality. Additionally, there was one free-response question in which the physical therapist had to provide what diseases and/or conditions for which they utilize virtual reality in the rehabilitation treatment. We chose these questions since they best gave us data that we needed in order to establish a definitive relation and give us results.

Using google search, a list of rehabilitation centers which have used virtual reality were found. We contacted several of these centers for over two months and asked the physical therapists to fill out the survey. This is called convenience sampling wherein a sample of participants are selected based on the people who are readily available to the researcher.

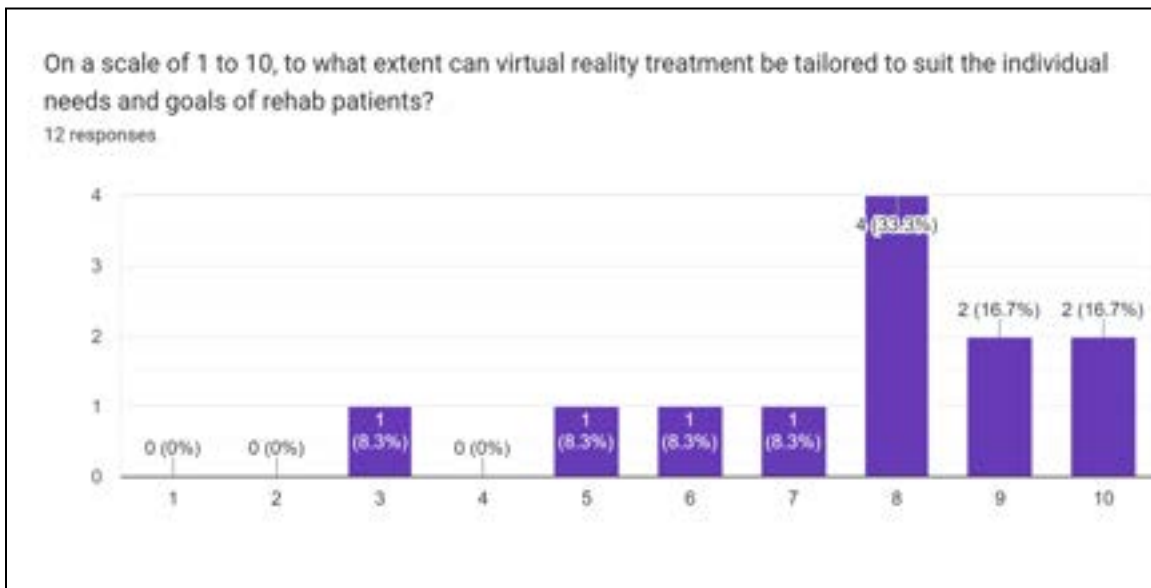
Results

The first question consisted of asking the physical therapists the effectiveness of virtual reality in promoting the recovery of patients in rehabilitation. A rating of one meant that virtual reality is not effective at all. A rating of ten meant that virtual reality is very effective. Out of the 12 physical therapists who filled out the form, it can clearly be seen that the majority of the respondents, 41.7% of them, gave a rating of 8 out of 10. One physical therapist gave a rating of 5 while another one gave a rating of 6. No ratings fell below a five and two physical therapists gave a rating of 10 out of 10.

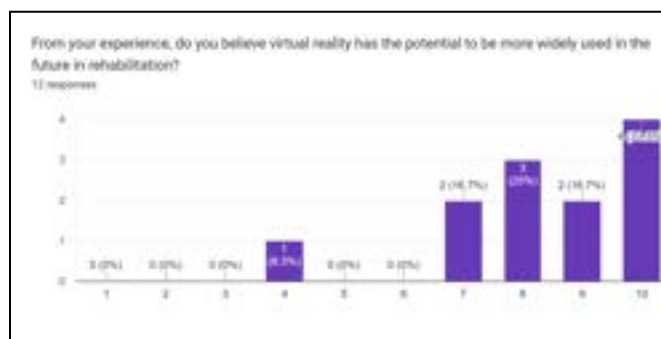


The second question consisted of asking the physical therapists if they agree with the statement that “virtual reality treatment enhances the effectiveness of traditional rehabilitation methods.” A pie chart clearly represents the results to this question. In total, 66.6% of respondents agreed with the statement, where 33.3% of them strongly agreed. On the other hand, 16.7% of physical therapists said they were neutral on the statement. This means that they don’t have a firm belief that virtual reality can or cannot enhance the effectiveness of traditional rehabilitation methods. Lastly, the remaining 16.7% of physical therapists disagreed with the statement. Out of the 12 physical therapists, no one strongly disagreed.

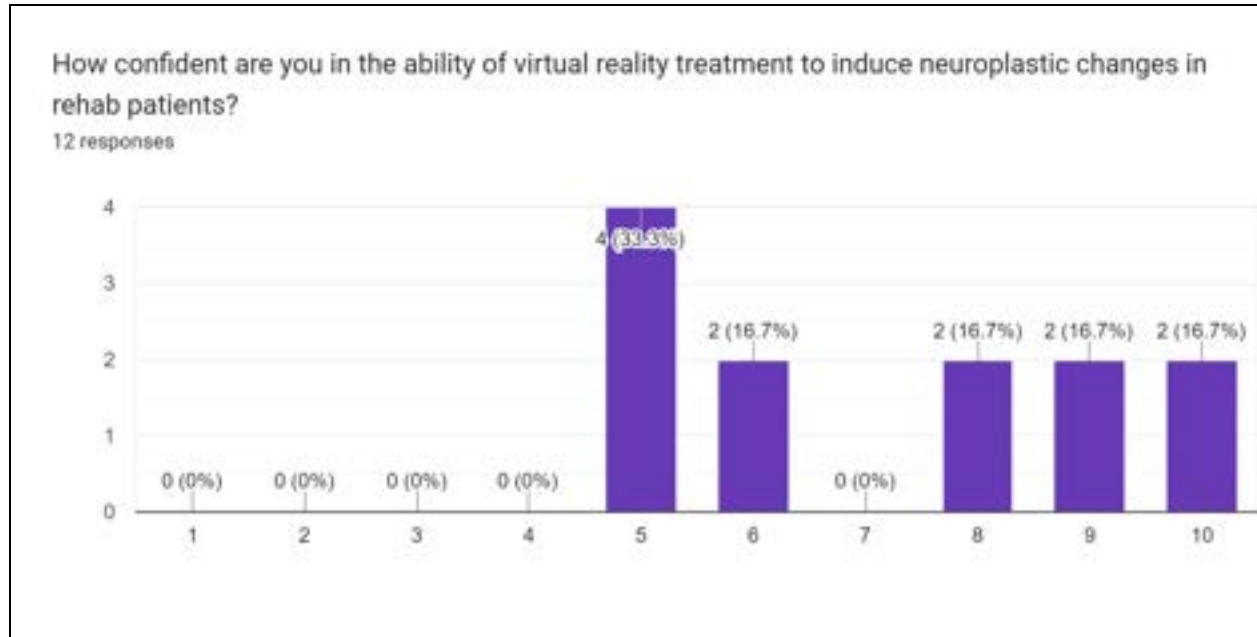
In the third question, the physical therapists were asked to what extent can virtual reality treatment be tailored to suit the individual needs and goals of rehabilitation patients. A rating of one meant that virtual reality cannot be tailored at all. A rating of ten meant that virtual reality can be tailored very much. Out of the 12 physical therapists, 66.7% of them gave ratings of eight, nine, or ten out of ten. 24.9% of them gave ratings of five, six, or seven out of ten. Lastly, one person gave a rating of three out of ten.



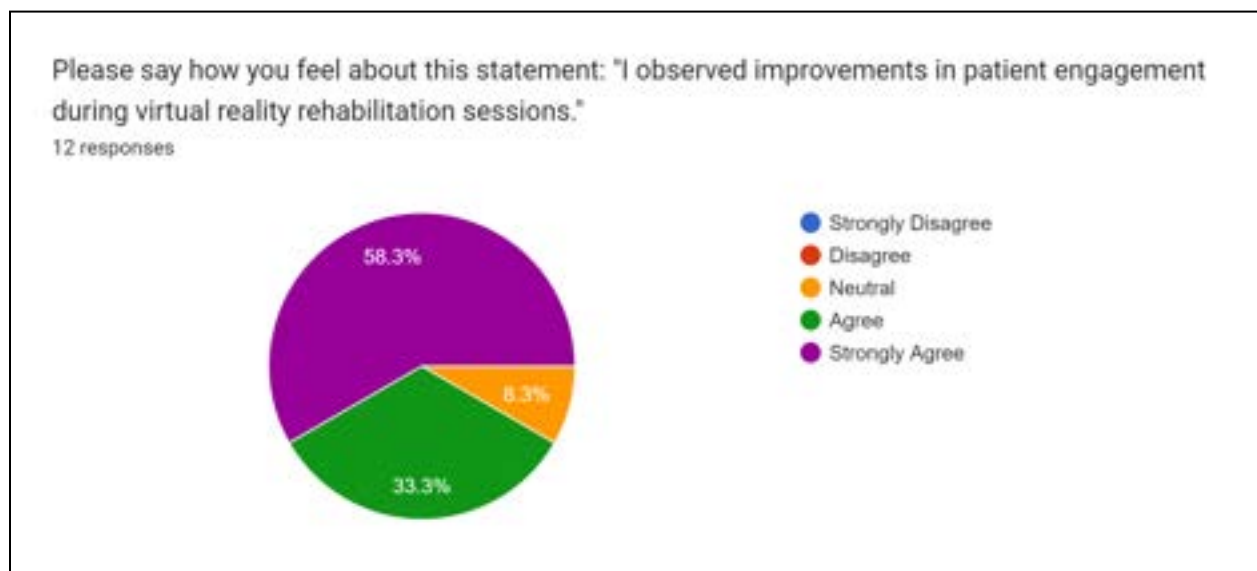
In the fourth question, the physical therapists were asked about the potential of virtual reality to be more widespread in the future. A rating of 1 means that virtual reality has no potential to be used more in the future. A rating of 10 means virtual reality has great potential to be widely used in rehabilitation in the future. Out of the 12 responses, 75% gave a rating of 8,9, or 10. 16.7% gave a 7 and 8.3% gave a 4.



The fifth question asks the physical therapists how confident they are in virtual reality as a means to induce neuroplastic changes in rehabilitation patients. A rating of 1 means no confidence at all while a rating of 10 means full confidence in the ability of virtual reality to induce neuroplastic changes. Of the 12 responses from physical therapists, 50% of responders gave a 8,9, or 10. 16.7% gave a 6 and 33.3% gave a 5.



The sixth question consisted of asking the physical therapists if they agree with the statement that, “I observed improvements in patient engagement during virtual reality rehabilitation sessions.” 91.6% of the physical therapists agreed with this statement, with 58.3% of them strongly agreeing. Additionally, only 1 person said they were neutral on the statement. This means that they don’t have a firm belief on whether they observed improvements in patient engagement during rehabilitation sessions.



The seventh and final question asks physical therapists some conditions they have encountered and treated using virtual reality as a form of rehabilitation. The most treated conditions from the experience of these physical therapists are Traumatic Brain Injury (TBI), Stroke, and Spinal Cord Injuries (SCI).

Conditions for which virtual reality is utilized in the rehabilitation treatment of patients	Number of Responses Given by Physical Therapist
Traumatic Brain Injury (TBI)	7
Stroke	9
Chronic Pain	3
Spinal Cord Injuries (SCI)	4
Multiple Sclerosis (MS)	2
Cerebral Palsy (CP)	3
Total Knee Replacement	1
Total Hip Replacement	1
Frozen Shoulder	1
Vestibular Disorders	2
Parkinson's Disease	2
Orthopedic Injuries	2
Functional Movement Disorders	1
Gait	1
Amputees ROM and Phantom Pain	1
Ataxia	1
Vertigo	1
Tinnitus	1
Orthopedic Conditions	1

Analysis

According to the data from the bar graphs and pie charts, it is evident that these physical therapists believe that VR is the future of physical therapy due to their personal experience and the benefits that it has brought to patients.

In questions one, three, four, and five majority of the physical therapists gave ratings of seven, eight, nine, or ten. This clearly shows that physical therapists are very confident in the ability of virtual reality to be effective in treating patients who have physical disabilities. Out of twelve physical therapists, there are only two of them who gave ratings below a five. This means that 10 physical therapists are either 50% or more than 50% confident in the ability of virtual reality to treat patients with physical disabilities.

In questions two and six with the pie charts, the majority of physical therapists chose to strongly agree or agree. This supports the idea that virtual reality can work alongside traditional physical therapy and there have been improvements in patients who have used virtual reality for rehabilitation.

Limitations & Future Studies

Physical therapists who have experience in using virtual reality were contacted using google search. Many of these physical therapists are at different locations in the United States. One limitation of the study might be that some of these physical therapists have a different amount of experience with using VR technology. This can greatly affect their responses to the google form. To further explain, a physical therapist who has over 5 years of experience in using VR may rate the technology as being very effective in treating patients. However, a physical therapist who has only had a few weeks of experience may rate the technology as being very ineffective. This is because they may have not seen any improved outcomes for the patient yet. To address this limitation in future studies, it's important to ask the physical therapist how much experience they have in using the technology. Physical therapists should include the amount of time they have been using VR technology as well in the google form. By doing so, an important confounding variable will be controlled.

Another limitation of this study with survey sampling is the lack of data. By getting more physical therapists to fill out these surveys it will allow for more data points. This will in turn lead to more precise results with a more definitive conclusion. Numerous data points will offset any of the outliers and highlight the true results of the study. This phenomenon is not possible when there are a limited number of responses. To help fix this limitation, future studies should aim to collect even more data through various methods of contact including but not limited to social media, cold calling, and cold emailing. These methods will help get rid of this limitation and lead to more accurate results.

In the field of physical therapy, there are many different virtual reality systems that are used by different rehabilitation centers. The main virtual reality systems used are the REAL system and Neuro Rehab VR. Each of these different systems can have different results on the patients. One system might have more physically demanding games for the patient to play. These

types of games can greatly improve the mobility of the patient compared to games that don't have physically demanding tasks. Additionally, some systems may have better animations and visual effects which can help engage the patient more. A physical therapist who uses such a system may rate virtual reality as being very successful to treat physical disabilities. This is because they may observe more positive outcomes with their patients. To help resolve this limitation, future studies should inquire about the type of virtual reality system that is used. Ensuring that every patient goes through the same set of games and tasks will make it easier to achieve reliable data.

It's important to note that virtual reality is used in conjunction with regular physical therapy techniques. Some examples of these techniques are range of motion exercises, gait training, proprioception training, etc^[11]. Each physical therapist who answered the google form may have used different physical therapy techniques in conjunction with virtual reality. Some techniques may have enhanced the effectiveness of virtual reality more than others. These physical therapists are more likely to view virtual reality in a more positive way compared to others. If a traditional physical therapy technique (which was used in conjunction with VR) was not effective in restoring one's mobility, the physical therapist may have attributed the low success rate of the patient to the ineffectiveness of the VR technology. This may have resulted in them perceiving the virtual reality technology as being unsuccessful in treating patients. To resolve this limitation in future studies, it's important to collect responses from physical therapists who have all used the same set of physical therapy techniques. Doing so will ensure that the type of physical therapy techniques used will not act as confounding variables when filling out the survey.

Conclusion

As stated previously, there are minimal studies in which physical therapists assess the effectiveness of virtual reality. To address this problem, a survey with 12 questions was sent to physical therapists in order to answer whether or not virtual reality is an effective form of rehabilitation for physical disabilities. These 12 questions were chosen specifically since they provide useful information on the physical therapist's experience with using virtual reality in their practice. The results of this survey support the idea that VR is an effective form of rehabilitation for physical disabilities. The results clearly show that virtual reality has the potential to be used widely in the future as well. From the study it can be concluded that virtual reality has the capability to revolutionize physical therapy and lead to better patient outcomes. These findings can have significant implications in the field of physical therapy as time progresses. More companies will start developing virtual reality headsets for patients to use. Additionally, physical therapists will adopt these new forms of technology in their practice.

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Melatonin and Activin A: Investigating a Novel Pathway for Enhanced Colorectal Cancer Treatment Through the Downregulation of Activin A Protein by Melatonin

By Sabrina Xu

Abstract

Colorectal cancer (CRC) is a major health problem worldwide becoming the third most commonly diagnosed cancer and the fourth cause of cancer-related deaths worldwide. Consequently, there is an increasing need to find further alternative pathological and molecular pathways of the disease to combat further metastasis. Previous studies suggest that transformative growth factor β (TGF β), a group of small chemical protein messengers, plays a major role in colorectal cancer's microenvironment, especially during its later stages, and it is widely agreed that further evaluation would be useful in future drug treatments and diagnosis for CRC. On the other hand, melatonin is a known anticancer agent for its beneficiary effects promoting apoptosis and limiting cell proliferation and migration. Therefore, one specific protein belonging to the TGF β family was chosen, activin A, and evaluated alongside the chemical melatonin, to evaluate the viability of the mechanism for a novel treatment for CRC. There has been no previous research on the relationship between melatonin and activin A in colorectal cancer cell development. To test this, molecular docking, two MTT assays, a caspase assay, a cell migration assay, and two ELISA assays were run. Findings suggest there is a great binding affinity between the targeted ligand and chemical. Melatonin was found to exhibit its anti-cancer properties in a colorectal cancer cell environment, and meanwhile downregulated the amount of activin A protein in the same environment. Hence, this study proposes that melatonin's anticancer effects in both short and long-term usages are due to its ability to downregulate activin A protein, demonstrating the medical potential melatonin could hold in future treatment for colorectal cancer.

Introduction

Cancer rates climb every year, with more than 1.6 million new cases being reported every year (Siegel & Miller 2018). Surgery and radiotherapy are common therapies for colorectal cancer (CRC), but they can have a wide range of adverse effects because of their low specificity and the damage they do to normal cells carrying out bodily functions. Furthermore, many patients relapse despite these basic therapies. (Johdi & Sukor 2020). Thus, it is crucial to have alternative and more effective treatments so CRC patients can have a better prognosis and a better quality of life.

Melatonin's Anticancer Effects

Melatonin is synthesized by the pineal gland and secreted into the bloodstream in reaction to darkness. Melatonin levels rise at night, alerting organs to enter a homeostatic pattern that allows the body to repair and defend itself against the spread of many diseases. It can operate as an antioxidant, which means that under extreme oxidative stress, it can activate a radical scavenger cascade to neutralize up to 10 radical products, unstable atoms that can lead

to cell damage (Talib & Alsayed 2021). This, together with other features such as prevention of metal-induced DNA damage and activation of antioxidative enzymes, is particularly useful in shielding DNA against oxidative damage and subsequent development to carcinogenesis, diabetes, arthritis, and more (Galano & Tan 2018). Therefore, melatonin is particularly powerful even in small doses, as it has been established that even 1 mM melatonin concentration can generate anticancer effects (Carbajo-Pescador & Ordonez 2013).

Besides melatonin's regulation of the circadian rhythm and energy distribution cycle, it also has an extra role in signaling pathways involved in key cell activities that, if interrupted, might induce accelerated cancer (Mirza-Aghazadeh-Attari & Mohammadzadeh 2020). Previous research has demonstrated that melatonin has anticancer characteristics. After 72 hours, melatonin was shown to dramatically reduce the survival of several colon cells such as HT-29, SW48, and Caco-2 cells in a dose-dependent manner (Chok & Koh 2021). Melatonin's capacity to trigger apoptosis in CRC cells is extremely beneficial. It affects the ER stress of protein expressions, leading to an unstable balance of harmful free radicals in CRC cells, which results in autophagy (Fernandez & Ordonez 2015). Melatonin has also been demonstrated to reduce proliferation and enhance apoptosis in CRC cells by upregulating tumor suppressor genes such as the miR-34a/449a cluster (Ji & Zhou 2021). Thus, melatonin's anticancer effects are wide and have great implications for future use.

Activin A Expression in Cancer Environment

Activin A is a paradoxical protein, with an elevated level of activin A in the early stages of CRC implying a protective benefit via cell cycle arrest and death. However, there have been instances of increased metastasis and tumor growth in response to high doses of activin A in the late stages of CRC. Suggested proposals to address this paradox concentrate on cells developing mutations in the SMAD4 gene, a tumor suppressor, to circumvent the growth-inhibiting impact of activin A (Refaat & Zekri 2021).

Recent studies have found that poor prognosis of CRC is associated with high stromal activity, where cells actively support tumor growth and progression, along with high levels of TGF β , particularly the protein activin A. Activin A plays a key role in promoting the spread of cancer cells within the TGF β superfamily, but has not been studied in the development of colorectal cancer in conjunction with melatonin (Zessner-Spitzenberg & Thomas 2019). Activin receptors are transmembrane serine/threonine kinases, which play a role in cell proliferation and apoptosis, along with two types of receptors that pair to form a complex, which transmits activin signals (Liu & Wang 2016). There are three kinds of type I receptors (ACVRIA, ACVRAIB, ACVRIC) and two kinds of type II receptors (ACVRIIA, ACVRAIIB). The SMAD2/3 cascade, initiated by the phosphorylation of the receptor, forms a dimer with SMAD4. This leads to the activation of p21, a primary transcriptional target of the activated SMADs, which then triggers a transcriptional response typically resulting in apoptosis. While still subject to further study, this is widely thought to be the mechanism of activins in the body (Zessner-Spitzenberg & Thomas 2019).

Further studies have demonstrated that activin A serves as a novel biomarker for CRC in humans, with mRNA levels being much higher in patients with CRC than in healthy patients. High activin A expression was associated with shorter cell survival, demonstrating that exposure to the protein enhanced the proliferation of CRC cell lines. This evidence supports activin A as a regulator of CRC proliferation, with elevated levels of activin A predicting poor outcomes in patients (Daitoku & Miyamoto 2022). Activin A was well associated with the stage of cancer, with the mRNA part of the α A subunit being overexpressed in most cancer samples. Overall, these findings demonstrate that colorectal carcinomas directly release activin A into the bloodstream (Wu & Li 2015). Activin A can accelerate CRC cell renewal and tumor growth, and therefore targeting it could be a viable technique for CRC therapy (Liu & Wang 2016).

Activin A's Role in CRC Metastasis

Activin A is increasingly recognized for its role in the metastatic process in CRC, carrying out many malignant effects of TGF β . A study of the CRC cell line found that the pro-metastatic properties of TGF β -treated cells depend on activin A (Staudacher & Bauer 2017). Activin A is among the first responders in wound healing. Elevated mRNA expression of INHBA, the gene encoding for the α A subunit of activin A, can be observed within 24 hours of a wound being inflicted (Zessner-Spitzenberg & Thomas 2019).

Activin A's upregulation of MMP proteases provides another mechanism by which it can facilitate metastasis. Specifically, it induces MMP-7, an enzyme that regulates tissue repair and cell migration by activin A, which is crucial for dissolving the basement membrane and other components of the extracellular matrix (ECM) to allow metastatic spread. (Yoshinaga & Mimori 2008). Activin A's early significance during wound healing and inflammation suggests a relationship in managing both inflammatory responses and antitumor immune functions (Zessner-Spitzenberg & Thomas 2019). Thus, researching activin A would provide crucial insight into the proliferation of CRC in patients, and new findings for the medical field.

While there has been previous research done evaluating the anticancer effects of melatonin, and the oxidative stress that activin A induces, there is no previous research connecting the relationship between melatonin and activin A in a colorectal cancer cell environment. This study proposes that melatonin can downregulate activin A protein levels in the colorectal cancer cell environment, leading to better patient outcomes. As such, the objective of this study is to examine this intricate relationship for potential future medical applications.

Materials and Methods

Molecular Docking

3D structures of melatonin and activin A were downloaded from PubChem and the Protein Data

Bank respectively and imported to PyRx, which screened them against each other to determine binding affinity and the viability of the potential drug targets. The molecule was then imported into Discovery Studio where they were matched again to visibly show their binding conformation.

MTT Assay: One-Day Treatment

Cell lines of colo-320 were seeded at 1,000 to 100,000 per well in two 96-well plates. The cells were then treated with melatonin in concentrations of 0.5 μM , 5 μM , and 50 μM . After preparation and a 1-day incubation of the 96 well plates, 5 mg of yellow tetrazolium MTT powder was diluted with 1 mL of phosphate-buffered saline, and after being vortexed to ensure the MTT was dissolved, 10 μL of the MTT solution was added to each well. After an incubation period of 1.4 hours at 37 degrees Celsius, 40 μL of media was drained from every cell and 80 μL of DMSO (Dimethyl Sulfide) was added to each of the wells to dissolve the MTT formazan. A wavelength of 595 nm was then spectrophotometrically used to evaluate the results.

MTT Assay: Seven-Day Treatment

The procedure was then repeated again but for an incubation period of seven days instead of one.

Caspase Assay: One-Day Treatment

Before starting the procedure, the Caspase-Glo 3/7 reagent was prepared by transferring the contents of the Caspase-Glo 3/7 buffer bottle into the Caspase-Glo 3/7 substrate and then mixed by swirling until the substrate was thoroughly dissolved to form the Caspase-Glo 3/7 reagent. The reagent was allowed to equilibrate to room temperature. Cell lines of colo-320 were seeded at 1,000 to 100,000 per well in a 96-well plate and then equilibrated to room temperature. 100 μL of Caspase-Glo 3/7 reagent was added to each well of the plate, which was then mixed extensively. The plate was then incubated at room temperature for 3 hours. Lastly, the luminescence of each sample was determined by a luminometer.

Cell Migration Assay: Two-Day Treatment

After colo-320 cell cultures were seeded in a 6-well plate, 10 μL of melatonin was added to 3 of the wells in differing concentrations, and one well was designated as the control group. Then, each well had 3 horizontal lines scratched onto the bottom using a 200- μL Pipette tip to stimulate the wounds. After an incubation period of 48 hours at 37 degrees Celsius, all the media was withdrawn. 1 mL of Methanol was added to each well to preserve the cells for microscopic examination, and after approximately two minutes, removed. The same procedure was repeated for Crystal Violet dye. Finally, to fully remove the stain, each well was washed out using water twice, each time for only about 10 seconds. Once the two minutes allotted to drying the plate passed, it was placed under a microscope at 100x magnification, and the 3 lines were observed. ImageJ was used to take 6 pictures of each of the different concentrations, with a considerable focus on the wounds themselves. Using the pictures, the length of each rift was measured to see how much the cells had grown back.

ELISA Assay: One-Day Treatment

After the colo-320 cells were seeded in each of 6 wells on a plate, 10 μL of melatonin was added to 3 of the wells in various concentrations, and the remaining 3 wells were designated as the control group. Following an incubation period of one day, 500 μL of Phosphate Buffered Saline was added to each well. Afterward, the cells were subjected to a -20°C environment for 30 minutes, then taken out to thaw at 20°C for 30 minutes. In total, this cycle of freezing and

thawing was done four times to lyse the cells and release the protein normally found in them. The samples from the wells were collected and placed into 6 distinct tubes. Then, activin A levels were measured according to the “sandwich” enzyme-linked immunosorbent assay procedure according to the manufacturer’s protocol. A standard curve for each protein was collected and the protein levels were documented using the curve.

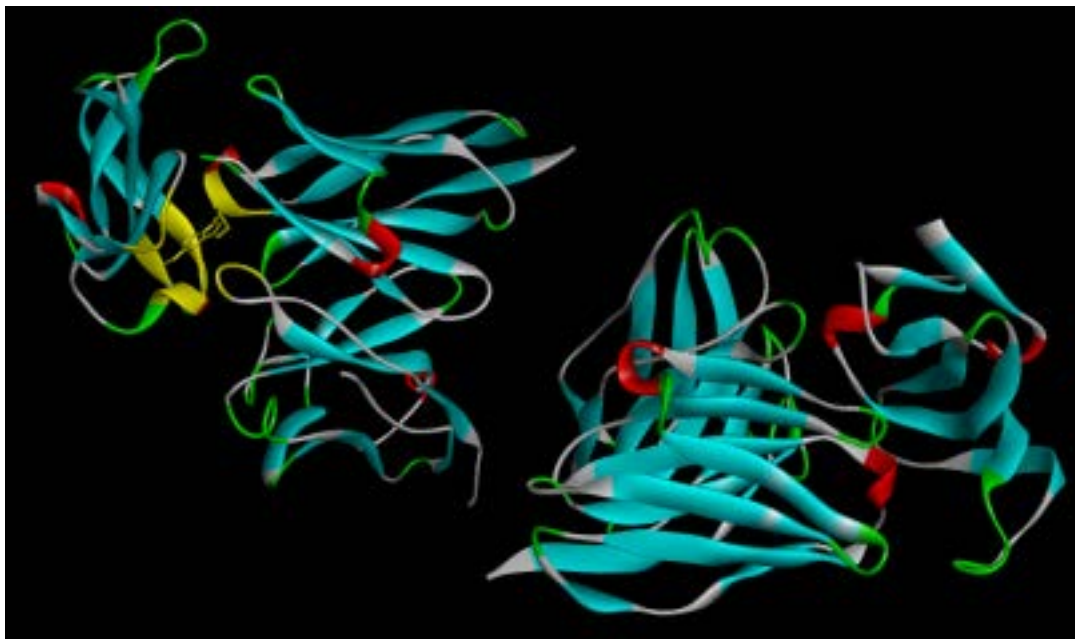
ELISA Assay: Seven-Day Treatment

The procedure was then repeated again but for an incubation period of seven days instead of one.

Results

Ligand	Binding Affinity	Mode RMSD Lower	RMSD Upper
		Bound	Bound
Activin-A	-6.0	0 0.0 0.0	0.0 0.0

Figure 1: Molecular Docking: Melatonin’s Binding Affinity with Activin A



Figure

2: Discovery Studio: 3D Structure Showing the Binding of Melatonin and Activin A

When melatonin and activin a were compared against each other using molecular docking (shown by the table), they were discovered to have a binding affinity of -6.0, which is considered high. This suggests that there is a great possibility the two interact together to produce a given effect in the body. The second 3D model depicts how the two molecules interact with each other (the yellow highlighted portion).

Melatonin's Effects on Colo-320 Cell Survival (1 Day)

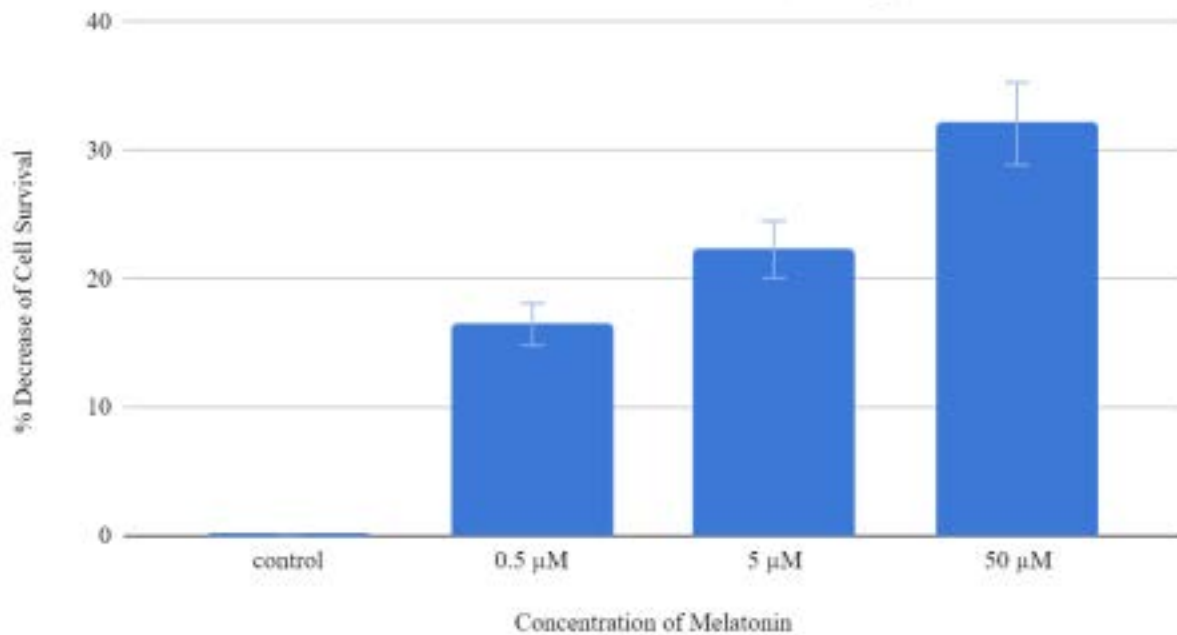


Figure 3A: One Day MTT Assay: Melatonin's Effects on Colo-320 Cell Survival

For a one-day treatment, the colo-320 cells showed significant cell death when treated at all concentrations of melatonin. However, treatment is most effective at melatonin concentrations of 5 μ M ($p < 0.001$) and 50 μ M ($p < 0.001$), showing the greatest cell survival decrease of 22.29% and 32.1% respectively. The control had a cell survival decrease of 0%, boosting a close to 100% survival rate for the untreated cells. These findings suggest that for shorter periods, melatonin has a significant anticancer effect on colorectal cancer cells, particularly at higher concentrations.

Melatonin's Effect on Colo-320 Cell Survival (7 Day)

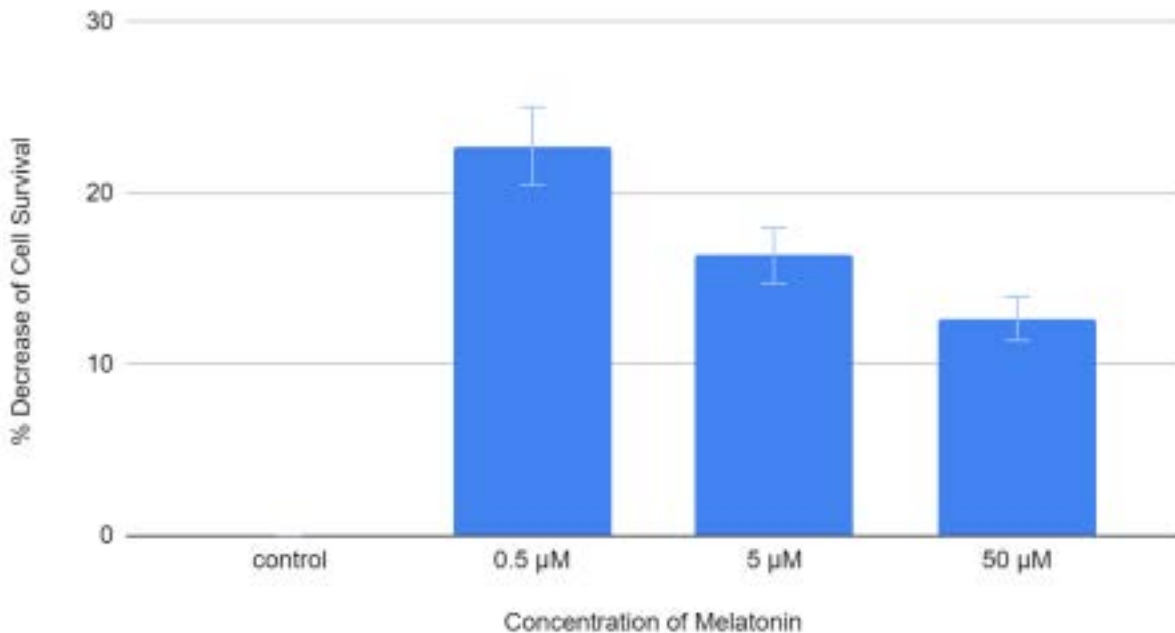


Figure 3B: Seven-Day MTT Assay: Melatonin's Effects on Colo-320 Cell Survival

On the other hand, for a seven-day treatment, the colo-320 cells showed significant cell death when treated with melatonin concentrations of 0.5 μM ($0.01 < p < 0.05$) and 5 μM ($0.01 < p < 0.05$), with a cell survival decrease of 22.76% and 16.36% respectively. Like the one-day treatment, the control had a cell survival decrease of 0%, boosting a 100% survival rate for the untreated cells. These findings suggest that for longer periods, melatonin has a significant anticancer effect on colorectal cells, usually at lower concentrations.

The contrasting results between the one-day and seven-day treatments show that larger concentrations of melatonin are more effective for shorter treatment periods, while lower concentrations of melatonin are more effective for longer treatment periods. This may have future implications for melatonin treatment plans, with melatonin's effectiveness showing an inverse dose-dependent relationship with the percentage of CRC cell survival. Nevertheless, the results show that for either treatment period, cell survival was significantly reduced in the presence of melatonin.

Melatonin's Effect on Caspase Activity

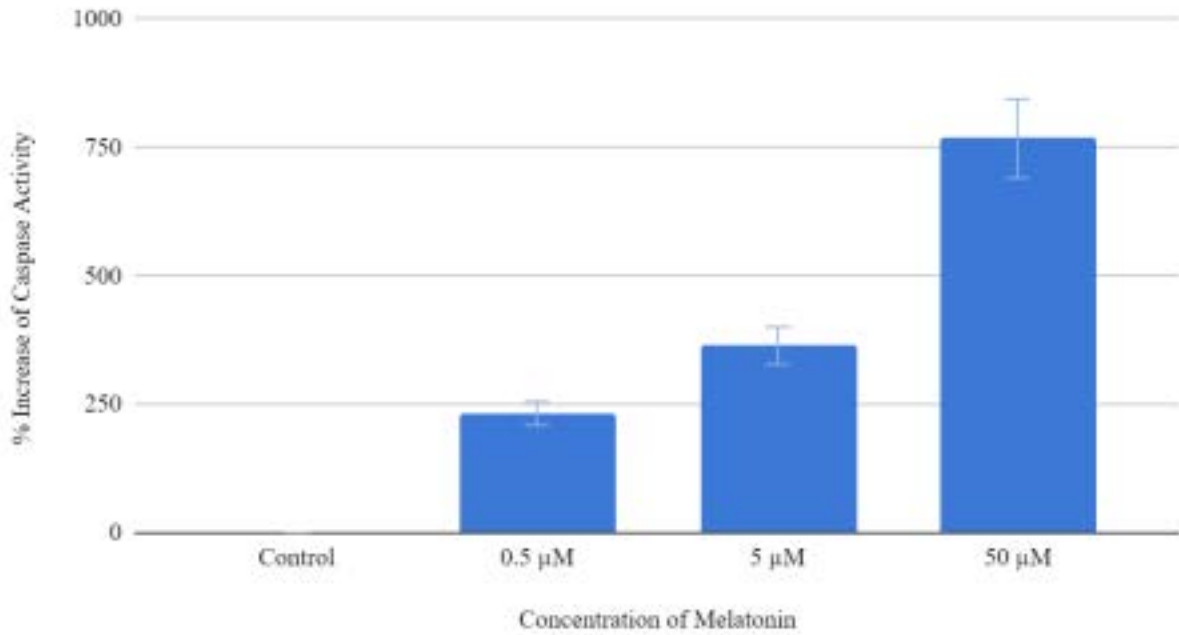


Figure 4: Caspase Assay: Melatonin's Effects on Colo-320 Cell Activity

Results from the caspase assay demonstrate that there is a significant increase in caspase activity as the concentration of melatonin increases. As caspases play an important role in apoptosis, their activity is an indicator of this kind of cell death. This suggests that there is a drastic increase in apoptosis of the CRC cells during higher concentrations of melatonin.

Effects of Melatonin on Rift Width

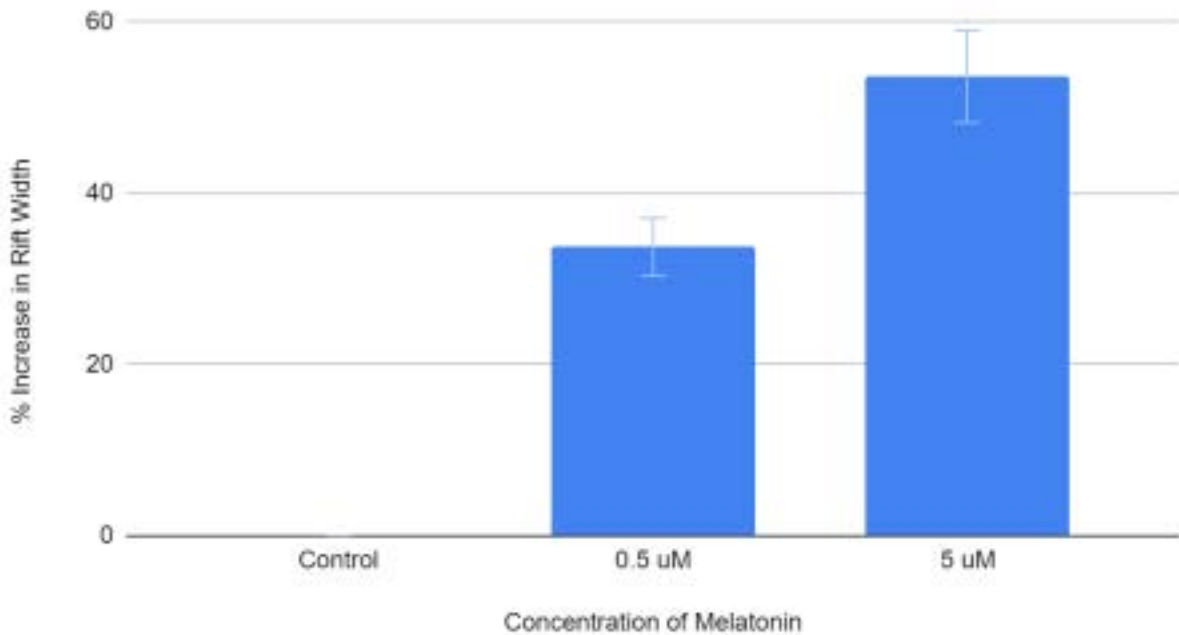


Figure 5A: Cell Migration Assay: Melatonin Concentration Effect on Rift Width



Figure 5B: Colo-320 Cell Migration Assay Control
Figure 5C: Effect of 0.5 μM Melatonin on Colo-320 Cell Migration Assay
Figure 5D: Effect of 5 μM Melatonin on Colo-320 Cell Migration Assay

Figures 5B, 5C, and 5D are pictures taken at 100x magnification of the colo-320 cell migration assay control and experimental groups. The results show that melatonin at concentrations of 0.5 and 5 μM significantly increased rift width, or the length between the two sides of the wound. Compared to the average control width of 160.717 pixels, treatment with 0.5 μM melatonin produced a rift width of 214.95 pixels while treatment with 5 μM melatonin produced a rift width of 246.93 pixels. Respectively, this caused an increase of 33.74% and 53.65% in rift length compared to the control. Treatment at 5 μM melatonin produced the greatest increase in rift length, showing that treatment of CRC is dose-dependent, with larger doses producing greater effects than smaller doses.

Melatonin's Anticancer Effects on Activin A (1 Day)

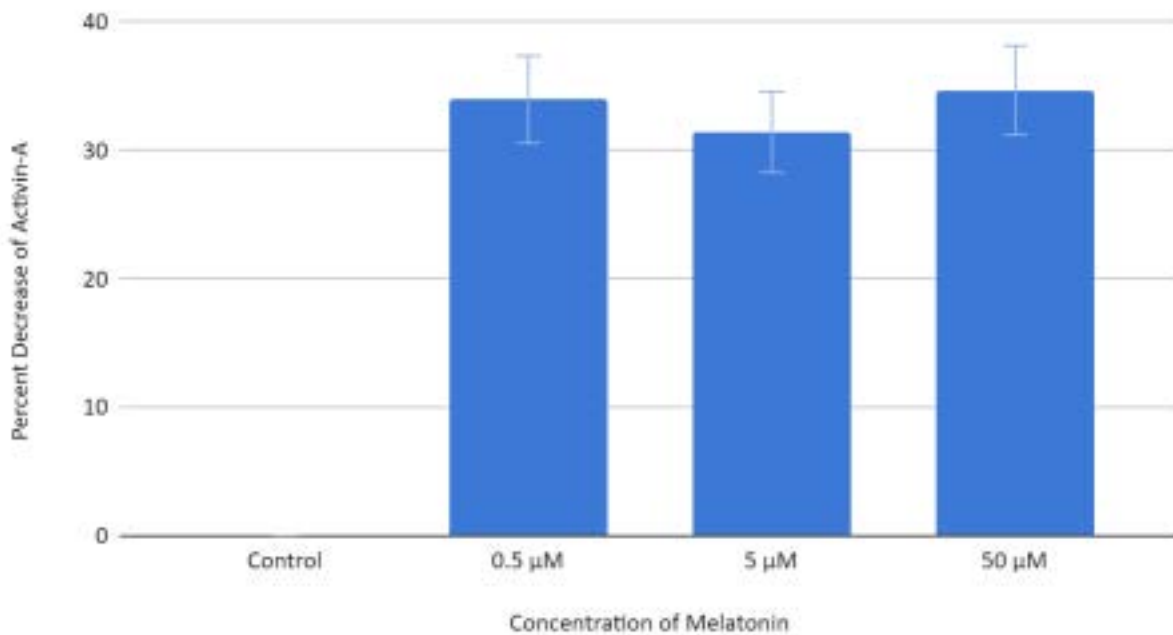


Figure 6A: One-Day ELISA Assay: Melatonin's Effect on Activin A

Melatonin's Anticancer Effects on Activin A (7 Day)

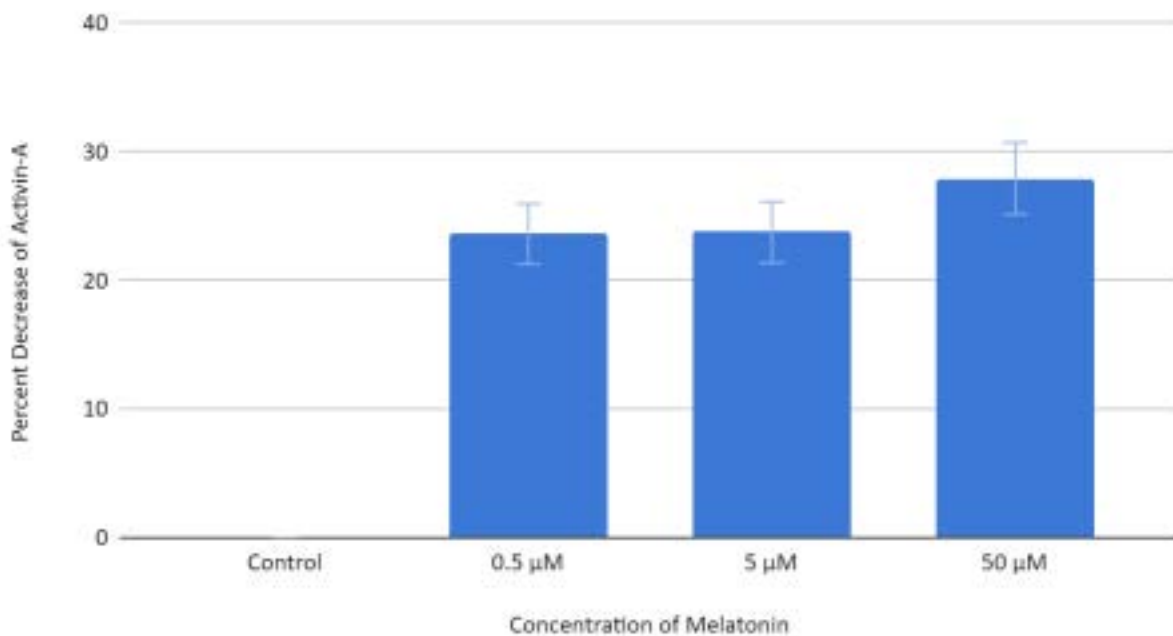


Figure 6B: Seven-day ELISA Assay: Melatonin's Effect on Activin A
Results from the first ELISA assay show no significance between the three

concentrations of melatonin, meaning they all induce similar effects on activin A protein. Results from the second ELISA assay also show no significance between the three concentrations of melatonin, so they also induce similar effects on activin A. However, the range for the one-day assay was higher than that of the seven-day assay, showing that in the short term, there would be a greater percentage decrease of activin A when using the same concentration of melatonin compared to the long term. Regardless, the percentage of decrease of activin A in the one-day assay was around 35%, and the percentage of decrease in the seven-day assay was around 25%. This shows that melatonin can downregulate the amount of activin A in the body.

Discussion

This study indicates that melatonin could have potentially considerable anticancer and anti-metastasis effects through its ability to decrease the amount of activin A protein. The data presented here contribute to a greater understanding of the effects of activin A on melatonin on the proliferation of colorectal cancer cells. These findings also add to the existing knowledge of melatonin and activin A on CRC.

The results of molecular docking show a high affinity between melatonin and activin A, which was the basis for the foundation of these experiments, designed to prove a relationship between the two.

Both MTT assays' results suggest that melatonin inhibits CRC cell survival. However, its effect is more pronounced in the short term, particularly at greater concentrations of 5 μM and 50 μM . In the long term, particularly at lower concentrations of 0.5 μM and 5 μM , similar effects can be observed as well. These results align with previous studies, like those of Chok et al. (2021) which demonstrated statistically significant decreases in cell viability at 1.5 μM and 2.0 μM respectively. Another study, done by Guangyu et al. (2021) also found that melatonin at concentrations of 0.2 - 2.0 μM significantly inhibited CRC cell viability in a time and dose-dependent manner.

To determine the ant-metastatic properties of melatonin, a caspase assay was performed 48 hours after treatment. It has widely been shown that melatonin can produce apoptosis and anticancer activity in CRC cells. Aligning with the results of the 1-day MTT assay, the caspase assay showed that melatonin produced the greatest amount of cell death at higher concentrations of 5 μM and 50 μM . The results of the caspase assay show that melatonin induces apoptosis within CRC cells in a dose-dependent manner, and works more effectively in shorter periods.

The cell migration assay was then performed to show the increase in rift width that results when colo-320 cells are treated with varying concentrations of melatonin. Results showed that higher concentrations of melatonin, particularly at 5 μM , were able to induce greater rift widths in the colo-320 cells, reinforcing the idea that melatonin has an anticancer effect on colorectal cancer cells.

To determine the relationship between melatonin and activin A, two ELISA assays were run. Results of the one-day assay showed that melatonin concentrations at 50 μM , 5 μM , and

0.51 μ M produced the relatively same percentage decrease of activin-A in cells, at around 35%. The seven-day assay showed that all concentrations of melatonin also produced the relatively same percentage decrease of activin-A in cells, at around 25%. This showed that in shorter periods, melatonin showed greater anticancer properties in its ability to decrease the percentage of activin-A. Taking into account the anticancer properties of melatonin shown by the MTT assay, caspase assay, cell migration assay, and ELISA assay, it is viable to conclude that there is a connection between melatonin's downregulation of activin A and its corresponding anticancer effects of cancer cells in the colorectal cancer cell environment. Our research indicates that due to melatonin's ability to downregulate activin A, it is a potent treatment for colorectal cancer through its anticancer and anti-metastatic effects.

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Overpriced & Oversold: Passenger Demand in the Airline Industry Before, During, and After COVID-19 By Sampan Mehta

Abstract

According to statistics from the Bureau of Transportation, on average, domestic passenger demand has increased annually by about two percent from 2000 to 2019. The COVID-19 pandemic in 2020 caused a decrease of about 58 percent in a single year. In the following year, there was an increase of 80 percent in domestic travel. So, after the pandemic, clearly, the passenger demand for travel soared to a point in which airlines were unable to satisfy the demand. The passenger demand greatly increased after the pandemic, which led to a halt in air travel due to severe restrictions. Business travelers saw a great increase due to the reopening of business travel, while leisure travelers contributed the most to travel demand post-pandemic. Airlines were completely unprepared for the surge in demand and had to act fast to solve staffing shortages and supply restraints. The staffing shortages and supply restraints had been caused by the industry's severe cutbacks on staff and reduction in supply due to the low demand caused by the pandemic. The travel demand had increased past the amount of supply that was available, and airlines had looked for ways to control the demand and become profitable again. The situation after the pandemic left airlines with unstable paths back to profitability, yet the demand had forced their way back to full capacity. This paper explores the rapid increase in demand for travel and how COVID-19 played a significant role in passenger demand. Additionally, this paper will cover how the airline industry managed the high demand as well as the important role that marketing strategies, flight pricing, and seasonal travel played in order to regulate demand.

Introduction

Airline flight ticket prices have always been costly and constantly fluctuate depending on seasons and availability. Shockingly, the airline market has taken a sharp turn into more expensive pricing, oversold flights, and an overall decline in customer experience. In light of recent events, airlines have been finding their way through the market as passenger demand was unstable and flight restrictions and requirements worsened the financial positions of airlines. Even though the world has largely returned to normalcy, airlines have kept their stubbornly high pricing in connection to soaring demand of customers on "revenge spending" sprees after being locked down for nearly two years. Airlines have taken advantage of their customers who are buying flight tickets with high prices in order to recoup the potential profits they lost and desperately need to stay in business. Through the use of airline marketing, flight pricing strategies such as dynamic pricing, seasonal demand, and the aftermath of COVID-19 in the travel industry, airlines have seen great returns even though profit margins remain slim. So, the next time you must fly domestically or internationally, do not be shocked to see sky-high prices when booking!

Methodology

When I was searching for the data and information for the paper, I looked specifically for comparisons and fluctuations in passenger demand over the years. In my comparisons, I searched for pricing differences, demand differences, and differences in the number of flights available to find a connection between these strategies and how they influenced passenger demand. I originally started the search process on Google web search to find news articles as well as poll data to understand how the passenger market responds to the improvements airlines make. Based on the gray literature, airlines worked towards their customers' high expectations by adding a variety of amenities and massive marketing campaigns to motivate people to travel by plane. After this initial broad web search, I searched scholarly journals and academic papers. While airlines improved their onboard services, they also strived to make the flying experience as comfortable as possible by providing digital check in services, better lounge experiences, baggage services, and more support overall. While these all have an effect on demand, the data shows that airlines started to make flying more rewarding by implementing mileage points systems and collaborations with a variety of credit card companies.

While I searched for the raw data, I was also looking for strategies airlines were using during and after the COVID pandemic as that was half of the equation that resulted in high passenger demand. A majority of the case studies and articles pointed out that the pandemic was one of the major factors that must have influenced passenger demand, so I returned to Google to search for the connection between COVID-19 and passenger demand. Some of the keywords I used in my search were "High passenger airline demand + COVID" and "Price increases + increased demand + pandemic." I found a variety of news articles and scholarly articles that did a lengthy analysis of how the aviation market changed in reaction to the pandemic and how there was an overall decrease in the supply of departing flights. While the passenger numbers and the prices rose, the supply decreased, which led to inflated demand and high pricing.

Results

Passenger demand for the airline industry has been fluctuating over the past few years, yet there has been an overall trend towards passenger growth in the Asia Pacific, USA, and European Markets, with demand going up by about 16 percent in January of 2024 ("Passenger Demand Up 16.6% in January."). This steady and incredibly rapid growth has led to predictions that the passenger demand will double by the year 2040 despite the recent challenges that the industry has faced over the past few years ("Passenger Demand Up 16.6% in January."). The first section of this paper will cover the possible factors that have led to rapid demand growth, including airline marketing, pricing strategies, and seasonal travel.

Airline Marketing

The airline industry is constantly changing, and the marketing strategies of airlines must simultaneously change with them. Airline marketing strategies are designed to reach new customers while keeping old customers engaged at the same time. Airlines also need to reflect on what their brands stand for and hope to appeal to customers who see their products as valuable to them. The main strategies that are used by airlines include promoting the types of services

offered, advertising through search engines and agencies, utilizing social media as an engagement platform to keep the customers connected to the brands, and lastly, using travel loyalty programs to keep the customers loyal to the brand (AltexSoft, 2024).

One of the first strategies includes determining whether the airline wants to promote low-cost services or luxury services. Low-cost carriers like Spirit and Frontier promote the most basic services yet keep their prices very low, which appeals mainly to low-budget travelers looking to save money. According to CNBC's report on budget airlines by Magdalena Petrova, low-cost carriers "keep costs down in part by limiting their amenities to the bare minimum" and "entice travelers with low base fares and then charge for add-ons such as seat selection, food, and luggage, all of which will frequently add up to more than the fare itself"(Petrova). In addition, low-cost carriers mainly focus on their own costs, and "they try to really go all out to minimize their expenses so that the money that they bring in is much more profitable" (Petrova). While these low-cost and budget carriers cater to budget travelers, there is a large and expanding market for leisure travelers looking to fly on higher-quality airlines. Leisure travelers focus mainly on luxury carriers like Cathay Pacific or Swiss Airlines, and with the extremely difficult competition, airlines get creative with their marketing to attract more customers, and they achieve this with the various innovative technologies in the market. People who fly on luxury airlines are not focused on the cost of the ticket but rather focus on what value or services they can receive based on the price of the ticket. Unlike budget carriers, luxury carriers focus on "amenities to enhance the overall travel experience," which include "in-flight entertainment systems, Wi-Fi connectivity, power outlets, and USB ports for charging electronic devices" (Al Thakafi). They also make sure to offer premium services and provide complimentary meals, checked baggage, and even itinerary changes (Al Thakafi). While low-budget carriers have catered to budget travelers who do not care much about the service and just want to fly to their destination, luxury, and full-service carriers make sure their customers feel comfortable and welcomed if they are willing to pay higher prices for it.

It is important to analyze how they have utilized technology in their strategic marketing strategies. One common strategy used by both types of carriers includes travel search engines and collaborating with external travel agencies to push advertisements for low fares or better value fares, as well as promotions for customer loyalty programs, which provide amazing benefits for travelers who remain loyal to that specific airline. There are many connections with loyalty points through credit and debit card companies which adds a mutual benefit to the airline's promotion and the bank card programs. With the rise of social media marketing, airlines have utilized it to publish content regarding exciting or low-budget travel destinations to provide inspiration for travelers. Lastly, another huge marketing strategy is the promotion of convenient services offered by the airline, such as online check-in, digital boarding passes, and some other digital services, such as airline apps.

How do these marketing strategies influence the strong passenger demand that has been on the rise? Airline customers have shown a highly positive response to the loyalty points programs, with poll data from a national survey citing 81 percent of people highly value loyalty

points and 73 percent of people constantly tracking the number of airline points earned through their credit or debit card (“New Polling Shows Consumers Highly Value Airline Credit Card Points.”). Based on the same poll data, 77 percent of people use their loyalty points within one year after collecting them. Loyalty programs have been a tremendous success for major airlines and have further proven to increase the surging demand for flying.

Other strategies airlines have lately implemented are also making passengers happy and likely to fly with that airline again, specifically on the soft and hard products offered (Bhaskara). One major feature that has gained positive traction is the improvement of seatback entertainment, with airlines like Cathay Pacific offering HBO MAX and Disney+, JetBlue offering DIRECTV, and many more airlines improving their in-flight entertainment (“Cathay Pacific first Asian carrier to bring HBO Max to every seat.”; Bhaskara). Other than the soft product, airlines have been investing in the hard product which mainly consists of seat improvements and new functions. Many domestic airlines have been promoting increased legroom seats, and major international carriers have been completely changing the cabin design to enhance comfort and overall customer experiences, such as Lufthansa’s Allegris cabin and Swiss International Airlines' new SWISS Senses design (Bhaskara). All these improvements in the cabin and the designated loyalty programs have played a significant role in boosting customer interest, leading to increased passenger demand.

Flight Pricing Strategies

Flight pricing strategies are always changing as the market continuously changes, and airlines need to focus on pricing strategies that can maximize their own revenue and profits. There are four major pricing strategies: competitive pricing, penetration pricing, lowest pricing, and dynamic pricing. Competitive pricing is when airlines use resources to get insight into their competition’s pricing and set their fares based on that (Jangid). Penetration pricing is when airlines use low fares to encourage customers to fly with their airline (Jangid). Lowest pricing strategies are used mainly by low cost carriers and aim to keep their prices lower than any other airline while keeping operational costs low (Jangid). Lastly, dynamic pricing, which is the most used strategy, allows airlines to change their prices in real-time based on the current market demand, seat availability, seasonal travel, and a variety of other factors. With dynamic pricing, airlines find ways to consistently maximize profits and revenue, quickly respond to market changes, focus on data-driven decisions, and increase their efficiency.

Seasonal Travel Cycles

Figure 1 is data on US passenger enplanements from the Bureau of Transportation statistics that show domestic airline passenger demand between January 2000 to December 2019 (“U.S Air Carrier Traffic Statistics through February 2024”). Seasonal travel cycles change yearly, but there is always a consistent travel demand increase during the summer months (See Figure 1 below), and price increases during the winter holiday months. During these two time periods every year, the increase in travel demand allows airlines to increase the costs as travelers

are consistently willing to pay more. If you search for flights during the school months, the prices will be significantly lower, as there is less demand to fly. However, due to the school holidays and work holidays, people have more availability to travel and are ready to spend thousands of dollars just for a flight ticket.

The airlines hold an advantage during these months, and even though the airline market is extremely competitive pricing-wise, if all airlines decide to increase their prices, the customer is at a loss. Not only are the prices incredibly high, but there is also an overcrowding of passengers, which makes traveling during these time periods extremely uncomfortable. Being a yearly customer, specifically during the winter holidays, the travel experience can overall be negative because first, you have to pay for overinflated flight tickets, deal with the crowds at the airports, and even struggle with overbooked flights and cancellations due to bad winter weather. These struggles continuously exist in the summer as well, with extreme heat, overcrowding, cancellations, and overbooking, all while spending thousands for a flight ticket. Not only are the passengers dissatisfied, but airlines also struggle to keep up with the overwhelming demand due to low staffing and decreased seat availability (“How airlines can handle busier summers—and comparatively quiet winters.”); however, the sky-high prices have been highly normalized in the airline industry during the holidays despite passenger dissatisfaction.

Monthly Passenger Enplanements for US Domestic Airlines

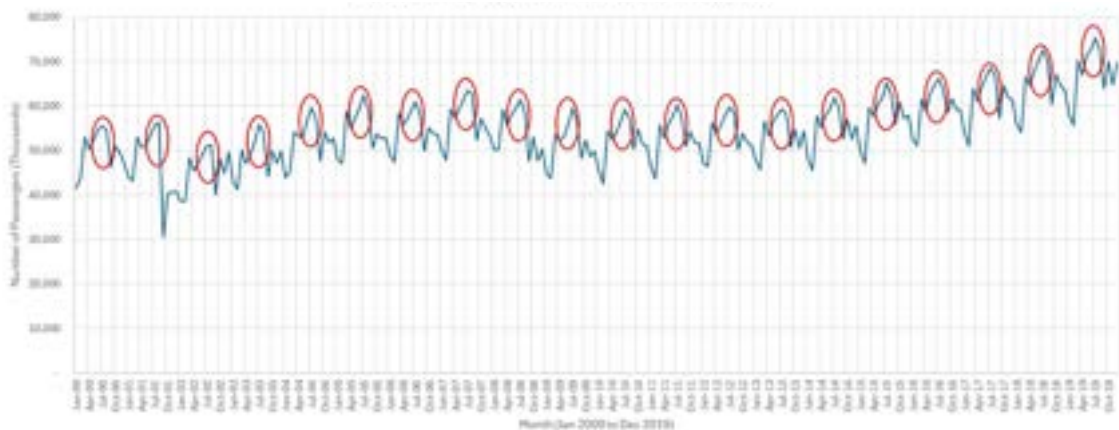


Fig 1: Seasonal travel cycles since 2000 from “Domestic Passenger - Passenger Enplanements (January 2000 - December 2023)”

Discussion

Reaching the end of this topic, it is time to look back at the thesis and questions answered throughout the paper. Since the end of 2020, flight prices have skyrocketed both internationally and domestically in the USA. These high prices were not met with resistance but rather more demand than ever by customers. The goal of this paper was to understand how and why consumers had been so eager to fly again to the point where they were not stopped by high prices. What made them resistant to the pricing? After conducting my research, the answer can

continue to expand, but it was due to the “revenge travel” period COVID-19 influenced shutdowns, smart marketing strategies airlines used to get back on track, and intentional capacity differences that inflated pricing. So, I concluded that the pandemic was a key component of passenger demand influence alongside the airline's marketing strategies. Additionally, findings suggested that most airlines’ strategies reacted to the coronavirus pandemic, which heavily affected the airline demand market. The overall enhancement of experiences, both on board and on the ground, made flying more worth it to the passenger market, leading to greater demand. In regards to the connection between seasonality and pricing, the demand was at its peak at major holidays, which was to be expected, and pricing is at its highest at these points as well.

Travel Before, During, and After COVID-19

What events had caused the travel boom after the pandemic? Simply put, travelers were frustrated with the harsh restrictions that dampened their plans, and they were ready to explore the world again at any given chance. Before the COVID-19 Pandemic, international and domestic travel was booming, with 4.5 billion airline passengers traveling in 2019 (ICAO, 2019). There were no worries about lower passenger demand, and airlines began making record profits as the global airline market made 838 billion dollars in revenue (Statista Research Department, 2024). But then, 2020 arrived with one of the most devastating pandemics that severely reduced passenger demand and brought airline market revenue down to dangerously low levels. People were unable to travel due to the pandemic restrictions, and airlines were forced to reduce their services, lay off staff, and spend even more money making sure the aircraft was clean in accordance with pandemic standards.

At the height of the COVID-19 pandemic, airlines faced new struggles other than reduced passenger demand. Countries started placing hefty quarantines on both passengers and crew, strict lockdowns, and health standards that were difficult to keep up with. In fact, more than 91 percent of people were forced to live in lockdowns and face quarantine measures across the world in early 2020 (Connor, 2020). Approximately 142 countries implemented quarantine measures and bans on all travelers, with China being one of the earliest countries to shut its borders and place stringent restrictions (Connor, 2020). All these factors have led to the financial downfall of airlines as many were struggling to continue operating under these requirements. They had tons of new expenses to pay, mainly including quarantine hotels for pilots, cabin crew, and other ground staff and operating flights that were near empty due to social distancing measures. All airlines started facing heavy losses at this height of the pandemic.

Now that the pandemic measures have been greatly minimized, airlines have a reduced burden of worrying about quarantine, social distancing, and other pandemic-related travel restrictions. Today, many have reached and even exceeded their pre-pandemic levels, and demand has favored them. Flight prices are definitely higher post-pandemic, but that is likely due to airlines wanting to catch up after the high-loss pandemic (French, Kemmis, 2024). Additionally, the pandemic has brought a big change to dynamic pricing, and that is inflating the

passenger demand by keeping a supply of seats low and costs high. With this strategy, airlines can continuously increase prices as they intentionally keep supply low to increase profits.

Based on future predictions and all the data gathered, it is unlikely that airlines will reduce their flight prices anytime soon as they continue to make up for what they potentially lost from the pandemic. With the high demand, they will continue to take advantage of this opportunity.

Conclusion

In summary, airlines have had a bumpy few years as they continue to find their way out of the pandemic, but the insanely strong demand has kept them afloat. Their marketing strategies and pricing strategies, combined with the increased willingness to travel, has resulted in high costs for flight tickets, and, based on the data, it seems that airlines will continue this pattern while demand is high and they reach a point of profitability. The airline industry is known for highly prioritizing profits, and their customers seem to be on a path of spending on travel. Ultimately, both airlines and passengers are looking to make up for what they lost over the pandemic: profit for airlines and travel experiences for passengers.

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Daegu's Competitive Edge in the Global Market of Textile Industries By Mingyu Chae

Abstract

Known as the “Milan of Asia,” the South Korean city of Daegu enjoys a thriving textile industry that dates as far back as the 1960s. Despite being one of the first textile industries to emerge, Daegu remains competitive in the global market even after other countries such as Bangladesh and Vietnam entered the scene. The purpose of this paper is to examine the factors that allowed such an unlikely city to emerge as a leader in textile production. The first two sections use existing literature about Korea's economic recovery after the Korean War to identify historical factors that contributed to the emergence and early success of Daegu's textile industry. These include the city's geographic location, strong workforce, and early access to technology. By synthesizing information from official city documents and recent economic analysis papers, the latter two sections identify the factors that currently allow Daegu's industry to thrive today, such as Korea's export-based economy, government support, and product diversification. These findings are important because existing strengths need to be magnified and supplemented for the textile industry to continue to thrive in the global economy.

Introduction

Today's fashion is all made possible by the textile industry. Famous clothing brands such as Gucci, Dior, Chanel, and Nike are all able to produce their products through the textile industries' production of their synthetic fibers, yarns, and other fabrics. Textile industries started in Britain around the mid-1700s when the Industrial Revolution occurred; as technologies and industrial methods spread around the globe, various nations such as India, China, Bangladesh, Vietnam, and Korea established their own textile industries. Among them, South Korea remains one of the most competent countries in the global market. This is surprising because most of the developed nations such as England, Germany, and Italy no longer focus on the textile industries as one of the primary industries. Rather, those developed countries focus much more on tertiary economic activities such as administration, real estate, business, and personal service. Therefore, it is essential to understand how Korea, more specifically the city of Daegu, has remained competitive in the global market of textile industries. Daegu's success in the textile sector can be attributed to a variety of factors, but the following will be the main points of emphasis in this research paper: Daegu's geographic location, the textile industry's early start, and Korea's economic structure.

Geographic Location

The Korean War was a proxy war between North and South Korea that began around 1950 and ceased after an armistice in July 1953. The conflict caused great casualties in various

cities of South Korea, including Seoul, Incheon, and Daejeon. Cities where battles occurred experienced devastation of approximately “600 thousand housing units, 46.9% of railroads, 1656 roads, and 1453 bridges totaling 49 km” (Lee 2).

First, Daegu's location played a crucial role in its ability to avoid attacks by North Korean forces during the Korean War, which in turn allowed its textile industries to emerge later without interruption. During the war, North Korean troops advanced as far south as Gwangju, resulting in only two major South Korean cities—Daegu and Busan—remaining safe from Northern occupation. This is shown by the second map from the left Figure 1 below, where the pink portion represents the areas occupied by North Korea and the blue represents areas still under South Korean control in August and September of 1950. This was as far as the North Korean army was able to progress; soon after, the South began to regain land with the help of the U.S. and other allies. Consequently, Daegu was protected against North Korean occupation, and it did not have to undergo extensive repair compared to other major cities. In fact, it became a bustling hub soon after the war's end.

Second, the war had created a significant demand for jobs, and many people, displaced or left unemployed by the conflict, were forced to migrate and find work elsewhere after the war ended. The North's invasion of the Nakdong River forced countless South Korean citizens to migrate to either Daegu or Busan. This massive population displacement led to those citizens earning jobs in Daegu—many of them entering the textile industry. Especially, female workers and weavers played an important role in resuming production in each factory after the liberation” (Jeon 79). Because of their participation, Daegu was able to satisfy the high demand of workers. Thus, Daegu's geographical location proved advantageous because it allowed the city to avoid structural damage during the war and because it was close enough to readily accept workers from nearby devastated areas.



Figure 1. Map of territorial invasions during the Korean War by NationalAtlas

Daegu's geographic location provided a third advantage for its textile industry: its proximity to two rivers. The quality of fabrics, a primary factor in the success of the textile industry, depends heavily on the quality of water used during production. Daegu benefits from two major rivers, including the Nakdong River and the Geumho River. The map below shows how these two rivers border Daegu.



Figure 2. Location of Nakdong and Geumho River by Ko, Kim, Jung, and Heo

These rivers provide a stable and clean water supply that is essential for producing high-quality fabrics. During the process of creating fabrics, huge amounts of water are used for bleaching, dyeing, and applying chemicals that fix the colors. According to Decathlon, each kilogram of dyed fabric requires roughly 100 to 150 liters of water. This figure does not even include the water necessary for the raw materials, like cotton, hemp, and latex. Therefore, having access to clean water and a place to dump the waste created from the industrial processes, was also part of the reason that Daegu was in the perfect position to produce high-quality textiles.

Early Access to Technology

The early start of Daegu's textile industry further positioned it for greatness in the global market. Daegu's textile industry started right after the Korean War, and a craze over nylon fabric in the 1960s caused the textile industry to surge. During this time, Korea focused heavily on industrialization and exports to stimulate economic growth. In the early stages of development, textiles became one of Korea's main exports, which played a crucial role in the nation's economic transformation. By 1973, Korea's textile exports "exceeded one billion US dollars, accounting for 47.3 percent of the country's total exports" (Etri Webzine). This early focus on textiles helped establish Korea as an export-based country, advancing its overall economic development ("The

Economic Miracle of South Korea"). In comparison, Bangladesh started to develop its textiles around the 1980s (Nabi), and Vietnam began to develop its textile industries around the 1990s (Huynh et al.). By the time other competitors were just beginning, Daegu already had a well-established textile industry and buyers around the world vying for its products.

An early start allowed Daegu's textile industry to harness cumulative knowledge and technology, propelling its evolution through successive waves of innovation. During the 1960s, Daegu adopted transformative technologies such as power looms, originally invented by Edmund Cartwright in 1785, which revolutionized fabric production by mechanizing the weaving process ("How Power Looms Work"). This innovation was complemented by the integration of spinning frames, which enabled the mass production of robust yarns and significantly reduced the labor-intensive task of hand-spinning cotton fibers ("Technology Development in Daegu Textile Industry"). Moreover, Daegu embraced synthetic fibers, manufactured from polymers not found in nature, further diversifying its textile production capabilities (Korea Textile Development Institute).

By the 1980s, Daegu had cemented its position as one of the global textile leaders due to its adoption of advanced technologies such as computer-aided designs, automated manufacturing using knitting machines and automatic looms, and enhanced fiber. These innovations facilitated more precise design capabilities, streamlined production processes, and improved product quality ("Technology Development in Daegu Textile Industry"). Additionally, advancements in dyeing techniques and digital printing allowed for greater customization and efficiency in textile production ("Technology Development in Daegu Textile Industry"). The willingness to adopt and improve foreign technologies allows the textile industry in Daegu to stay ahead of other competitors even though other countries might have had a larger workforce.

Export Economy and Government Support

Once Korea recovered from the Korean War and became a developed country, the country's export economy, free-trade agreements, and government support continued to give the industry its competitive edge.

Korea's emphasis on its export economy facilitated the success of its textile industry, enabling it to gain significant profits from exports. President Park Chung-hee, who served South Korea from 1963 to 1979, was instrumental in supporting Korea's export-driven strategy. President Park consistently attended the Enlarged Conference for Export Promotion meetings, which facilitated the development of healthy trade relationships with foreign nations. This fostered an environment where industries, including textiles, could thrive internationally. Because of this, the export of textiles helped Korea achieve remarkable economic growth rates, averaging about 40% per year during peak periods ("The Economic Miracle of South Korea"). Korea's historical reliance on textile exports laid the groundwork for continued export success in various sectors. This success continues into the modern day. According to the Observatory of Economic Complexity (OEC), Korea earned about \$7 billion annually from its textile industries in 2022. This substantial export revenue illustrates Korea's capability to export a significant

volume of textile products worldwide, contributing to the development of both Daegu and Korea's textile industries as a whole ("South Korea").

Similarly, free trade agreements (FTAs) have been pivotal in amplifying the success of Daegu's textile industry. During the 21st century, Korea has entered into FTAs with major economies, including the United States, the European Union, India, Singapore, and Vietnam. These agreements have facilitated the vast export of Daegu's textile products by reducing or eliminating tariffs and trade barriers, thereby making Korean textiles more competitive in international markets. The Korea-U.S. Free Trade Agreement (KORUS FTA), for instance, has significantly boosted trade between Korea and the U.S., with U.S. goods and services trade with Korea totaling \$167.8 billion in 2019 (Office of the United States Trade Representative). Such agreements have enabled Daegu to access a broader market, driving further growth in its textile industry.

Recognizing the significance of the textile industry to Korea's economy, the government continues to support the textile industry through various forms of financial aid, tax benefits, and infrastructure developments. Because Korea is a Confucianist country with a strong central government, policymakers could easily implement their planned policy. As Smith writes, "the higher degree of state autonomy in Korea could also rectify the conditions of both private and public sectors throughout a reorganization of government ministries and even industrial sectors" (77). As a result, Daegu has benefitted from significant financial assistance that has enabled local businesses to invest in advanced technologies and expand their operations. Businesses received tax incentives that reduced the financial burden and further encouraged growth and development (Daegu Metropolitan City). Daegu thus became an ideal environment for the development of the textile industry.

Proactive Innovation

Along with this strong foundation, Daegu's textile industry remains competitive in the global market because it continues to use advanced technologies and low-cost labor, and because it has been flexible to the demands of the market by diversifying its products.

Entering the 21st century, Daegu continued its trajectory of innovation, leveraging technologies such as e-textiles—fabrics that enable electronic components such as batteries, lights, sensors, and microcontrollers to be embedded in them—for health monitoring, eco-friendly textile products, and pioneering techniques such as 3D knitting and printing. These advancements not only catered to evolving consumer needs but also underscored Daegu's commitment to technological leadership in the global textile market (Onechang Co.)

Second, the textile industry is inherently labor-intensive, requiring a substantial workforce to meet production demands. Daegu has been able to leverage its low-cost labor force to satisfy this high demand efficiently. The availability of labor has allowed Daegu's textile industry to maintain competitive production costs, thereby enhancing its ability to compete in the global market. This supply of low-cost labor has been instrumental in the city's ability to meet

global demand and move on to export-oriented growth, resulting in increased foreign exchange and further industrial growth (Daegu Metropolitan City).

Third, product diversification has played a significant role in the growth of Daegu's textile industry. While traditional textiles—those without any special features such as waterproofing—remain as the cornerstone, Daegu has expanded its production capabilities to include technical textiles. These are specialized textiles designed for technical performance and functional properties, such as airplane seats, baby diapers, and conveyor belts. This diversification has not only broadened the market reach of Daegu's textile products, but has also positioned the city as a leader in innovative textile solutions, catering to a variety of industries beyond traditional clothing and apparel (Daegu Metropolitan City).

Conclusion

A unique trajectory shaped by historical, geographical, and economic factors has given Daegu a competitive advantage in the global textile market. The city had a solid foundation to grow upon thanks to the early growth of the textile industry and its relative safety during the Korean War. Early success was magnified by Korea's strategic emphasis on an export-based economy, strong government support, and effective industrial policies. The city's ability to leverage low-cost labor, product diversification, and favorable trade agreements enabled it to excel in the global market. Furthermore, Daegu has always been at the forefront of textile technology, from the 1960s with the adoption of power looms and synthetic fibers to the present with e-textiles and 3D knitting. In addition to increasing productivity and product quality, these developments have allowed the city to expand the range of textile products it offers, meeting the needs of various markets and applications.

The city's textile sector has initiated sustainability initiatives aimed at reducing environmental impact throughout the production lifecycle ("Sustainability Initiatives in Daegu Textile Industry"). For instance, companies such as ONECHANG Materials began to utilize PFC-free (products that do not release chemical compounds that are harmful to the environment), recyclable, and biodegradable products. These changes have the potential to put Daegu in an advantageous position as far as sustainability, but continued efforts on this front will be necessary to ensure proper management of Korea's limited resources as the textile industry scales up to compete with larger competitors who can grow at a faster rate.

Therefore, Daegu must evolve again to compete successfully with large textile industries in China, Vietnam, and India, which produce both raw textiles and garments. The large factories in such countries initiate conglomerates that are gradually making it impossible for small textile industries in Daegu to compete due to their difference in labor forces and product availability. Moving forward, Daegu must either increase the quality of its products or shift its offerings to match the global demands for more natural fibers and non-woven fabrics. Without finding a niche, the city's global relevance will decline even if it remains the national hotspot for textiles.

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Palladium Catalysed Processes in Active Pharmaceutical Ingredient Manufacture By Sia Patni

Abstract

This paper describes the critical role of palladium catalysis in the synthesis of Active Pharmaceutical Ingredients (APIs). Organic chemistry is key in API synthesis, involving well-defined steps and catalysis, particularly with palladium, offering versatility, mild conditions, and economic benefits. The Suzuki reaction, Buchwald-Hartwig reaction, and C-H activation are examples of these palladium catalysed reactions. The Suzuki reaction, a palladium-catalysed cross-coupling, is extensively employed in drug manufacturing, exemplified in the synthesis of flavonoids and the production of Losartan, a widely prescribed hypertension medication. The Buchwald-Hartwig reaction, including carbon-nitrogen bond formations, is crucial in pharmaceutical synthesis, exemplified by its role in the production of Lasmiditan and Nitroarenes. C-H activation, breaking and modifying carbon-hydrogen bonds, presents a direct approach in synthetic routes, with sulfoxonium ylides playing a pivotal role. Despite challenges, C-H activation is valuable in late-stage functionalization, particularly in the modification of peptides, enhancing synthetic efficiency. Palladium-catalysed reactions are crucial for future advancements in materials, pharmaceuticals, and complex molecular structures.

Introduction

An Active Pharmaceutical Ingredient, also known as an API, is a key component in a drug that produces the intended therapeutic effect. The production of APIs typically involve complex chemical processes, and they undergo rigorous testing to ensure their safety and efficacy. Once the APIs are manufactured, they are often formulated into a final dosage form (i.e. in tablets, capsules, or injections) with the necessary excipients to create the finished pharmaceutical product.^[1] APIs are usually organic compounds, and organic chemistry plays a crucial role in their synthesis. They also design and optimise chemical reactions to obtain the desired compound with high purity and in sufficient quantities.^[1] The synthesis of APIs in organic chemistry involves a series of well-defined steps to create the desired chemical compound with therapeutic properties. The process can be complex, typically involving several catalytic steps, and may vary depending on the specific API and its intended use.

Catalysis is a fundamental concept in organic chemistry that facilitates and accelerates chemical reactions. Catalysis plays a crucial role in organic synthesis, offering several advantages, such as increased reaction rates, improved selectivity, and reduced energy requirements.^[2] There are two main types of catalyst: organic and metal. Metal catalysis is more established and routine, it is the main focus of these reactions. Frequently used transition metal catalysts include copper (click reaction), iron (reductions), osmiums (ozonolysis), and many more.^[3] One particularly useful catalyst in organic chemistry, and therefore pharmaceutical synthesis, is palladium.

Palladium catalysis is extensively used in organic synthesis. It is valued in organic synthesis due to its versatility, tolerance of functional groups, mild reaction conditions, high efficiency and wide substrate scope. Palladium catalysts exhibit high versatility and are effective in a wide range of reactions - this versatility allows for the synthesis of diverse organic compounds. Its cross-coupling reactions enable the formation of carbon-carbon bonds, a crucial aspect of organic synthesis.^[4] These reactions are valuable for constructing complex organic molecules, such as pharmaceuticals and agrochemicals. They also often tolerate a variety of functional groups, allowing for the tolerance of multiple functionalities within the same molecule.^[5] Many palladium-catalysed reactions can be conducted under mild conditions, including room temperature and atmospheric pressure, this is helpful for the synthesis of temperature-sensitive or reactive compounds. Palladium is an abundant and relatively inexpensive transition metal. Mild reaction conditions often translate into reduced energy requirements and a more environmentally friendly synthetic route.^[4] These qualities make palladium-catalysed reactions crucial tools for modern organic chemists in the design and synthesis of diverse and complex molecules.

This paper explores palladium catalysis, exemplifying its significance and vitality. Specifically, we will focus on notable transformations such as Suzuki coupling, Buchwald-Harwig, and C-H activation. These choices are made based on the prevalence, use, and valuable function these reactions have in organic synthesis.

Suzuki-Miyaura

The Suzuki-Miyaura reaction was first reported by Japanese chemists Akira Suzuki and Norio Miyaura in the late 1970s, and is also known simply as the Suzuki coupling reaction. It is an organic reaction, classified as a cross-coupling reaction, where the coupling partners are a boronic acid and an organohalide and the catalyst is a palladium complex. The Suzuki reaction is a popular method for forming carbon-carbon bonds both in discovery chemistry and in commercial manufacturing; it has quickly become an integral part of modern organic synthesis.^[6] It is a palladium-catalysed cross-coupling reaction that is valued for its broad substrate scope, high functional group tolerance, and applicability to a variety of aryl and vinyl halides along with its versatility, compatibility and pivotal contribution to diverse disciplines, including materials science and drug discovery.^[7]

The Suzuki reaction has a high prevalence in drug manufacture. It is important in the development of a variety of therapeutic agents, including anticancer drugs, antiviral agents, and anti-inflammatory compounds. This widely adopted cross-coupling reaction in synthetic organic chemistry is in high demand, and crucial in organic chemistry.^[7] The reaction occurs in mild reaction conditions which makes it compatible with highly-functionalized molecules, Its efficacy reduces side reactions showing its selectivity. This allows for the development of more complex molecular structures required in drug manufacture.^[8] The reaction has some economic benefits as it uses boronic acids, which are easily synthesised and more commercially available making the

reaction cost effective and easy for large scale manufacturing. The Suzuki reaction is able to tolerate a variety of functional groups, such as amides, ketones, and esters which is important in drug manufacture where diverse functional groups are needed. This extensive utilisation in organic synthesis, particularly for carbon-carbon bond formation and biaryl synthesis, has proven crucial in producing valuable compounds like pharmaceuticals and natural products. Indeed, the Suzuki-Miyaura reaction is the second most frequently used reaction in drug discovery and development.^[7]

An example of the effectiveness and use of the Suzuki reaction is in the synthesis of flavonoids. Flavonoids are a group of natural compounds with variable phenolic structures and are found in plants. They typically possess a number of medicinal benefits, including having anticancer, antioxidant, anti-inflammatory, and antiviral properties.^[9] The Suzuki reaction is particularly useful in the synthesis of flavonoids due to its ability to form carbon-carbon bonds between aryl (or vinyl) boronic acids and aryl halides or pseudohalides. The Suzuki-Miyaura enables the synthesis of flavonoids of natural origin and derivatives from precursors bearing sensitive substituents. The reaction allows for the convenient synthesis of diverse flavonoids suitable for biological activity studies by using different organoboron starting materials in the final stages of the synthesis, as shown in figure 1. This also allows for large scale synthesis due to the stability and commercial availability of a wide range of boronic acids/esters, and the ease of working up the reaction mixture. The ability to efficiently synthesise flavonoid derivatives using the Suzuki reaction has been used for drug discovery and development. Derivatization of these molecules through cross-coupling substrate scopes further allows for the exploration of structure-activity relationships for potential pharmaceutical applications.^[10] This example shows the application of the Suzuki reaction and its effectiveness as a palladium catalysed reaction.

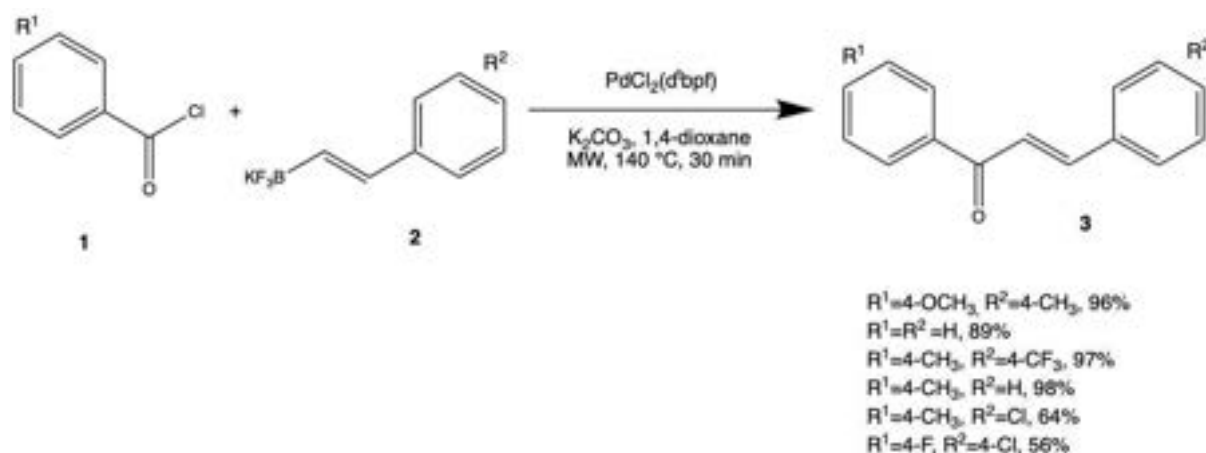


Figure 1: A reaction scheme showing the synthesis of various Flavonoids.

The Suzuki reaction is also used in Losartan, one of the most prescribed medicines in the world, and is the first angiotensin II receptor antagonist discovered by scientists at Dupont to treat high blood pressure and hypertension. The synthesis of Losartan involves several steps, and the Suzuki coupling reaction is one of the key transformations in its production. The Suzuki

coupling is used to form the biphenyl ring system in Losartan. A boronic acid derivative, often containing the desired substituents for Losartan, is coupled with a halide or triflate compound. Under the catalysis of a palladium complex, the cross-coupling reaction occurs between the boronic acid and the halide or triflate, resulting in the formation of the biphenyl ring, as seen in Figure 2, establishing the specific carbon-carbon bonds required in the Losartan structure.^[11] The use of a palladium catalyst in the Suzuki reaction provides high selectivity for the cross-coupling process, enabling the controlled formation of the biphenyl ring in the desired location. Late-stage functionalization in Losartan synthesis, achieved through the Suzuki–Miyaura coupling, introduces specific functional groups after forming key structural elements.^[12] This versatile palladium-catalysed cross-coupling streamlines the process for analog and derivative design, contributing to efficiency and diversity in drug development with potential pharmacological variations, Showing the selectivity of the Suzuki reaction.

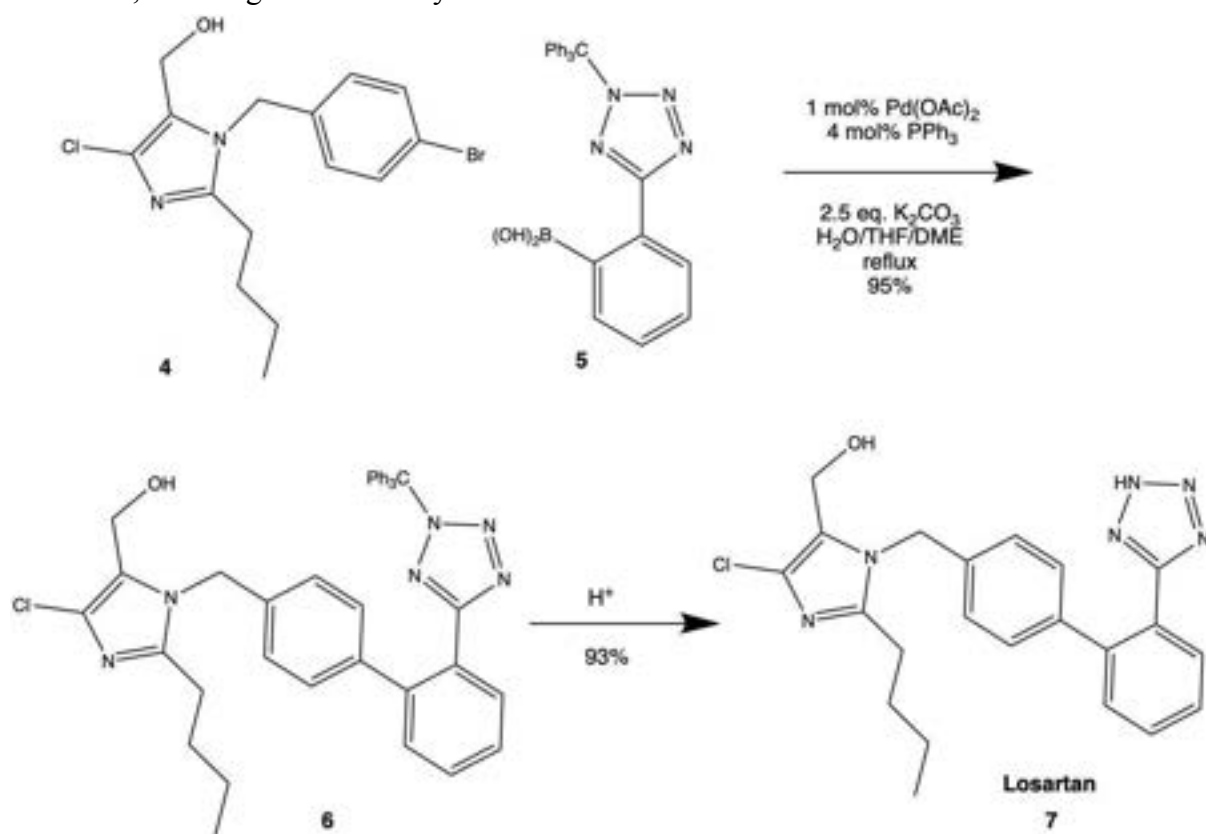


Figure 2: A reaction scheme showing the synthesis of Losartan, one of the most prescribed medicines in the world.

The Suzuki-Miyaura reaction is a valuable synthetic tool in organic chemistry, offering mild reaction conditions, broad substrate scope, compatibility with functional groups, and versatility in various synthetic applications, making it widely used in both academic and industrial settings. The Suzuki reaction has a high prevalence in drug manufacture and is important in the development of a variety of therapeutic agents. Now more than ever, there has been a general upsurge of interest in this reaction, mainly aimed at improving the catalytic systems in terms of efficiency and sustainability. Palladium reactions like Suzuki coupling are

still at the forefront of chemical research and development, in the fields of both homogeneous and heterogeneous catalysis.^[7]

Buchwald-Hartwig

The Buchwald-Hartwig reaction is a widely used method for the synthesis of carbon-nitrogen (C-N) bonds. It was developed by Stephen L. Buchwald and John F. Hartwig in the 1990s. It involves the palladium-catalysed coupling of aryl halides (or pseudohalides) with amines or amine derivatives. The reaction includes an aryl halide or pseudohalide (Ar-X), Amine (NR'₂), a palladium catalyst (with ligand) and a base.^[13] The Buchwald-Hartwig reaction is highly versatile and tolerates a wide range of functional groups, making it applicable to diverse synthetic challenges. The choice of ligands and reaction conditions can be tailored to optimise the reaction for specific substrates. It also has a high regioselectivity and often forms the most stable, singular regioisomer when multiple regioisomers are possible, proving valuable in complex molecule synthesis as this leads to higher yields and purity.^[14]

The Buchwald-Hartwig reaction plays a crucial role in modern organic synthesis, contributing to the efficient and controlled construction of arylamine-containing compounds with broad applications in various scientific and industrial fields. Similarly to the Suzuki reaction, the advances in the reaction significantly impacted the synthesis of pharmaceutical agents, offering more efficient and straightforward synthetic routes and supporting a modular strategy for analog synthesis.^[4] The method's importance lies in its utilisation of aromatic amines as starting materials, which are crucial components in the synthesis of biologically active compounds, including kinase inhibitors, antibiotics, and central nervous system (CNS) active agents.^[14] It is widely used in the pharmaceutical industry for synthesising complex molecules, especially those containing arylamines and accommodates various aryl halides and amines, allowing for the incorporation of diverse building blocks into drug molecules. Continuous developments in ligand design, including the synthesis of new and improved ligands, have enhanced the efficiency and scope of the Buchwald-Hartwig reaction.^[14]

The Buchwald-Hartwig amination of nitroarenes was achieved for the first time by using palladium catalysts bearing dialkyl(biaryl)phosphine ligands. These cross-coupling reactions, featuring nitroarenes with diarylamines, arylamines, and alkylamines, resulted in the formation of substituted arylamines.^[15] The dialkyl(biaryl)phosphine ligand is a specific type of ligand that contains a phosphorus atom coordinated with two alkyl groups and a biaryl moiety. The choice of this ligand is crucial for achieving the desired catalytic activity and selectivity in the amination reaction. Buchwald-Hartwig ligands, including the dialkyl(biaryl)phosphine ligand, has a vast range of selectivity and is widely adaptable. The ligand contributes to the stability of the palladium complex and influences the reactivity of the system. The reaction involves aminating nitroarenes, which usually have a nitro group (-NO₂) on an aromatic ring. In the presence of a palladium complex with a dialkyl(biaryl)phosphine ligand, nitroarenes react with an amine source, resulting in the substitution of the nitro group with an amino group. The

Buchwald–Hartwig reaction allows for the selective formation of carbon-nitrogen (C-N) bonds providing a direct and controlled method to introduce amino groups on aromatic rings.^[16] Similarly to other palladium catalysed reactions, the Buchwald–Hartwig amination of nitroarenes is valued for its selectivity, versatility, mild reaction conditions, and broad applicability across different fields of synthetic chemistry.

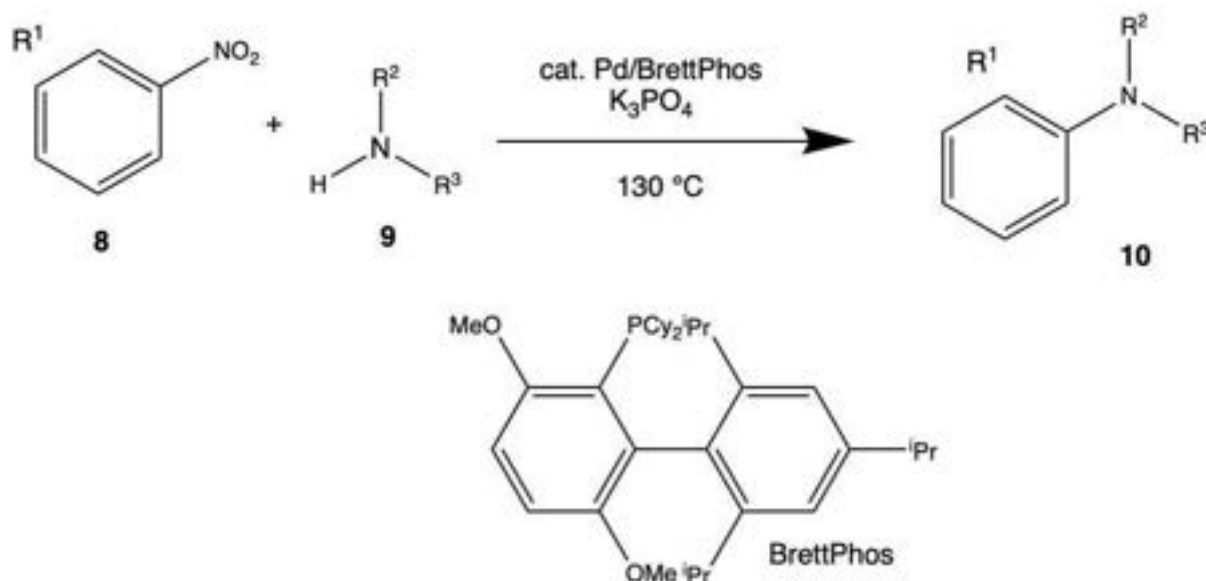


Figure 3: A reaction scheme showing the Buchwald–Hartwig amination of nitroarenes achieved using palladium catalysts bearing dialkyl(biaryl)phosphine ligands.

Lasmiditan is a medication used for the acute treatment of migraine in adults. It is a selective serotonin receptor agonist, specifically targeting the serotonin 5-HT_{1F} receptor. As researched by Borgel, Jonas, and Tobias Ritter, there are many ways to make Lasmiditan proving it to be versatile and have economical value.^[11] This advantage is particularly valuable in drug development, allowing for the exploration of new molecules with potentially heightened potency and therapeutic benefits. In this reaction, the synthetic pathway involves Lasmiditan 14, formed via the Buchwald Hartwig reaction. Coupling 12 with the palladium catalyst yields 13 with high efficiency. The ability to make various analogs of Lasmiditan using this synthetic pathway provides a platform for a comprehensive substrate scope analysis. Researchers can systematically modify different components to explore the structure-activity relationship, enabling the identification of optimal molecular configurations for enhanced drug efficacy.^[17] This versatility in analog synthesis not only contributes to the refinement of Lasmiditan but also opens avenues for the discovery and development of novel drug candidates with improved pharmacological properties. In the broader context, the synthetic pathway showcases its utility in drug discovery and materials science, highlighting its pivotal role in advancing pharmaceutical research and therapeutic innovation.

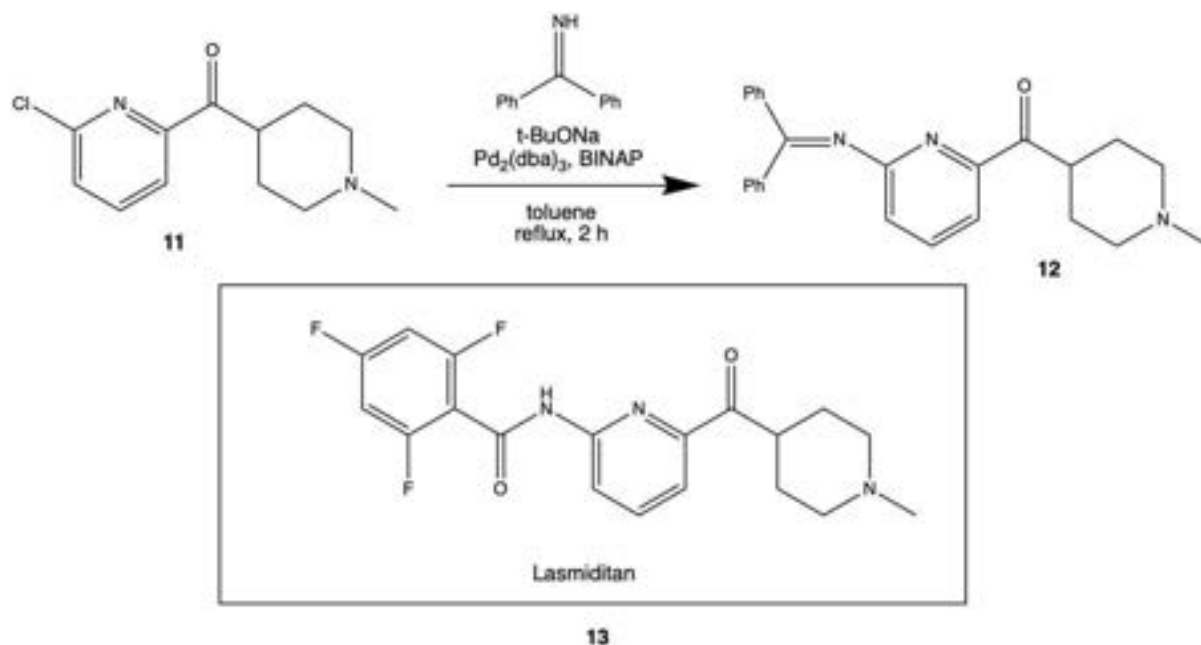


Figure 4: A reaction scheme showing the synthesis of Lasmiditan

Twenty-five years ago, Buchwald and Hartwig started a remarkable evolution in C–N coupling reactions with their pioneering research findings. This innovation has since evolved into a pivotal tool in organic synthesis, comparable to other well-established palladium-catalysed processes like the Suzuki–Miyaura and Sonogashira coupling reactions. Consequently, it has been widely applied in both academic and industrial settings, and ongoing research continues to explore new possibilities and extend the boundaries of this transformative method.^[18]

C-H activation

The general reaction scheme for C–H activation involves the cleavage of a carbon-hydrogen (C–H) bond in an organic compound, often facilitated by a transition metal catalyst. The metal catalyst typically forms a coordination complex with the organic substrate, leading to the activation of the C–H bond.^[19] Traditionally, organic reactions have often focused on the manipulation of functional groups, but C–H activation represents a more direct and efficient approach to modify organic molecules by utilising C–H bonds directly. It is typically catalysed by transition metal complexes, and various metals, such as palladium, rhodium, ruthenium, iridium, and others.^[20] C–H activation has gained prominence in organic chemistry as a powerful tool for streamlining synthetic pathways and facilitating the construction of diverse molecular structures.

C–H activation has gained significant attention in recent years due to its potential to streamline synthetic routes and create more efficient and atom-economic processes. It has found applications in various areas of organic synthesis, including the construction of scaffolds in pharmaceuticals, agrochemicals, and materials. It allows chemists to access novel molecular structures and has become a powerful tool in the development of more efficient and sustainable synthetic methodologies.^[19] Another factor that makes C–H activation useful in drug

manufacturing is its use in late-stage functionalization. Late-stage functionalization refers to the introduction of functional groups into a molecule at a late stage of the synthetic route, typically near the end of the synthesis. C-H activation is often employed as a method to selectively functionalize specific C-H bonds in a complex molecule during the late stages of a synthesis.^[21] This strategy allows chemists to introduce new functional groups at desired positions without the need for pre-functionalized starting materials. It streamlines the synthetic process by minimising the number of synthetic steps. There are, however, still some challenges with C-H activation. Enhancing the applicability of C-H activation reactions is challenging due to the need for developing methods compatible with a broader range of functional groups, as many existing methods require the absence of certain coordinating groups. C-H activation reactions with high catalyst turnover numbers are still very rare in the literature and 10 mol % is a common catalyst loading in this field.^[22] In summary, C-H activation is a potent tool for late-stage functionalization in drug manufacturing, but challenges remain in expanding its applicability and increasing catalyst turnover rates.

Used extensively in the field of C-H activation, sulfoxonium ylides are carbene precursors that provide a safer alternative to highly reactive and unstable diazo compounds. Sulfoxonium ylides are chemical compounds that contain a sulfonium group attached to a positively charged carbon atom, forming a ylide structure. They are versatile reagents known for their application in various organic reactions, particularly in cyclopropanation and C-H activation reactions.^[23] These reactions are valuable in organic synthesis as they allow the direct and selective modification of C-H bonds, which are abundant in organic compounds. Sulfoxonium ylides enable mild and selective activation of C-H bonds under the influence of transition metal catalysts. This selectivity is crucial for functionalizing specific C-H bonds in complex molecules. The employment of transition metal catalysts, including palladium, rhodium, or copper, not only facilitates the C-H activation process by overcoming the high activation energy barriers associated with breaking C-H bonds but also extends to the application of sulfoxonium ylides in these reactions.^[24] This combined approach has proven valuable in the total synthesis of natural products and biologically active compounds, leveraging the selective modification of specific C-H bonds for enhanced synthetic efficiency. Sulfoxonium ylides in transition-metal-catalysed C-H activation provide a potent tool for accessing diverse functionalized compounds, contributing to advancements in synthetic methodology and complex molecule synthesis.

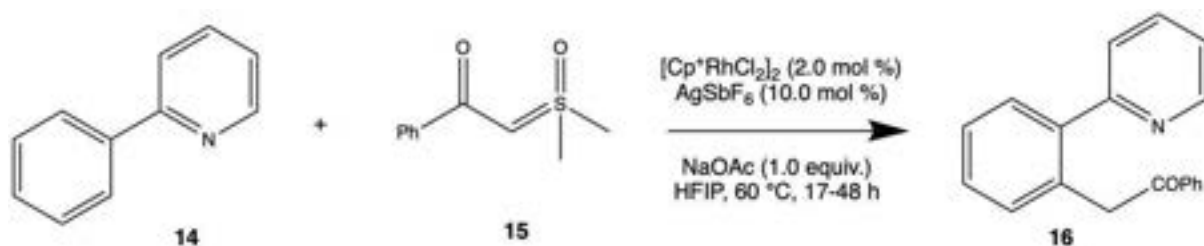


Figure 5: A reaction scheme showing the synthesis of sulfoxonium ylide, which is used extensively in the field of C-H activation.

Peptides are molecules composed of amino acids and they are fundamental to the structure and function of proteins in living organisms. Peptides exhibit significant potential in the fields of proteomics, diagnostics, and drug discovery. Although natural peptides remain crucial, chemically altered unnatural peptides have demonstrated heightened biological activities and improved therapeutic potentials when compared to their natural counterparts.^[25] Late stage functionalization allows for the selective incorporation of specific functionalities into a peptide sequence, providing flexibility and control over the peptide's properties. In regard to C-H activation, late-stage functionalization of peptides involves the direct transformation of C-H bonds within the peptide backbone or side chains into other functional groups, thereby introducing new chemical moieties or modifying existing ones. This strategy can be advantageous as it avoids the need for pre-functionalized starting materials and can simplify the synthetic process.^[26] Controlling the regioselectivity of functionalization in a peptide through site-selective C-H activation is essential. This goal can be accomplished by employing directing groups, steric hindrance, or other strategic design elements. Challenges in C-H activation of peptides include issues related to regioselectivity and potential side reactions, however, researchers are exploring innovative strategies to expand the scope and efficiency of C-H activation in peptide chemistry, aiming to provide new tools for the late-stage modification of peptides with enhanced precision and versatility.^[26]

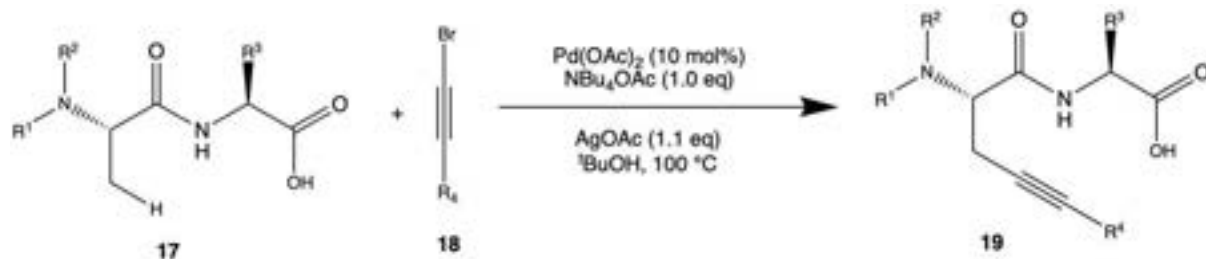


Figure 6: A reaction scheme showing the late-stage modification of peptides

Conclusion

This paper has explored the pivotal role of palladium catalysis in the synthesis of Active Pharmaceutical Ingredients (APIs), emphasising its significance in the pharmaceutical industry. The versatility and efficiency of palladium-catalysed reactions have proven instrumental in the construction of complex molecular structures, contributing to the synthesis of a diverse array of pharmaceutical compounds. This paper discusses the Suzuki Miyaura Reaction, Buchwald–Hartwig reaction, and C-H activation. The Suzuki reaction has emerged as a powerful tool for the formation of carbon-carbon bonds. It is a versatile and efficient method for the late-stage functionalization of a wide range of substrates, including complex molecules and pharmaceutical intermediates.^[7]

In the future, it is evident that palladium-catalysed reactions will continue to shape modern organic synthesis, providing innovative solutions for the challenges faced in the development of new materials, pharmaceuticals, and complex molecular structures. We hope that

this paper serves as an thorough introduction of the vital role played by palladium catalysis in the synthesis of APIs, emphasising its importance within the pharmaceutical industry. By analysing the Suzuki Miyaura Reaction, Buchwald–Hartwig reaction, and C-H activation, we aim to provide an understanding of these powerful reactions and their applications. Our aspiration is that this work contributes to the broader knowledge base in organic synthesis, inspiring further research and innovation in the development of new materials, pharmaceuticals, and intricate molecular structures.

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Taking DIY to the Classroom: The Abstract Bookshelf Project with the Sparkling Mindz School By Sophia Park

Introduction

A student artist from Yongsan International School of Seoul in South Korea conducts an experimental workshop with students in Sparkling Mindz School in Mumbai, India, to do something unprecedented: to connect on a deeper level through the process of abstract art, creating a piece under one hour, and then transform that interpretation into a gift a bookshelf with an IKEA style manual. This approach aims to integrate meaningful educational steps with the modern liberal arts and design as the positive aims of the student's efficiency, creative thinking, and personality.

On the other hand, the interlinking of significant barriers between abstract art and functional furniture offers participants a novel and actual learning intervention that would aid in honing their artistic aptitude, stimulating creativity, and community solidarity. The case study report brings more specificity to the selected procedure of taking abstraction to the tangible.

The transformation process not only shows how creative students can be but also fosters pride and accomplishment in the student's projects. The following report offers a general insight into the applied methodologies, the workshop phases, and the roles of the students and the facilitators. Additionally, it looks at the effect of this initiative on the students, the effectiveness of the strategies to engage the students, and the quality of results obtained from the activities.

Finally, this report looks into the possibility of extending the given approach to other learning environments and identifying prospects for the further development of progressive education for the given target group. Hopefully, this research can pave the way for a more approachable, minimalist, environmentally sustainable pedagogy that instills DIY engagement.

Project Overview

The Abstract Bookshelf Project is formally defined as a three-hour learning-teaching process in which students actively participate. Ultimately, the process will result in the production of a single piece of furniture. This type is practical and symbolizes the student's innovative contribution and ownership of the classroom. The initiative is a two-part workshop inspired by the idea that students must learn about abstract art and a brief session about 3-dimensional models. During the first part of the lesson plan, students learn about such general classifications of abstract art, which provides them with a space for being inventive in their artwork.

In the second part, these artistic visions are incorporated into functional designs through the employing of 3D modeling applications from Sophia Park for the creation of a chair. The main aims and objectives of the project are to increase the student's appreciation of art, to provide better opportunities for social relatedness using collaborative experiences through the construction of the 'art-womb,' and to develop a design concept that can be used as a model for similar learning institutes to maintain and encourage creativity and the sustainability ethos (Iyengar, 2023).

Workshop Process

The workshop was divided into two sessions to maximize student engagement and creativity. For instance, it will follow the following order. There were two principal strands in the one-day workshop: The first would focus on a particular theoretical topic; the second would accommodate the type of learning that fosters students' imagination and enhances their learning.

1. Preliminary and preparatory session with the checklist for participants and course outline.

- The first part of the activity was an orientation presented by Sophia Park, where she briefly discussed abstract art and then showed the students some aspects of abstract art.

- All the learners were given an inspiration card and drawing item of their choice: colored pencil, felt pen, oil pastel paint brush, and acrylic tube.

- To avoid bias, the students did not explain what would be drawn on the large canvas. Each student was given a one-minute turn to draw before passing the canvas to the next student. The students were to draw on top of each other.



Photo: Final Drawing

2. Session 2 was a discussion about the process itself, inviting students to learn from each other about the intentional and improvisational process.

- The drawing continued until each student had staked more than once in the artwork.

- The last drawing was then posted, and the students were asked questions related to their understanding and experience of silent collaborative drawing during the activity and the impact of this technique on their creativity.

- This conception for the joint design was developed whenever the abstract drawings of the students were connected into one layout, which, in turn, was reconstructed into a layout the students used to design from.

Impact on Students

The Abstract Bookshelf Project had a significant impact on the students involved in the workshop:

1. Optimized Flow State

- The creation of abstract art and then turning it into an object helped the students achieve flow, which may be defined as a mental state operation in which an individual participating in an activity is wholly absorbed in the feeling of intensified concentration, investment, and enjoyment

(Iyengar, 2023). This flow state involved concentration, enjoyment of the activities, and a sense of completion. It was thus positive and satisfying for the student's needs.

- This approach to organizing the workshop was engaging and encouraged the students to use their artistic skills while allowing them to practice. They were given creative liberty, probably a rarity in schools managed using conventional methods (Iyengar, 2023). This idea gave them some independence that fostered the growth of their skills and techniques in art.

2. Deeper Bonding with Classmates

- Organization of the classroom according to the principles of collective creation of exhibitions effectively improved collaboration between students, better interpersonal relationships, and unity (Iyengar, 2023). When the students get involved in an everyday activity, they acquire interpersonal relationships and teamwork as they have to share their ideas and work as a group.

- It also consisted of the aspect of sustainability—less is more, that is, students' conscious efforts towards designing objects with less impact on the environment. This particular component of the workshop education enabled the students to leave a sense of accountability concerning the physical environment and nature, which also made them understand the tenet of sustainability in the current world (Ciufu et al., 2024).

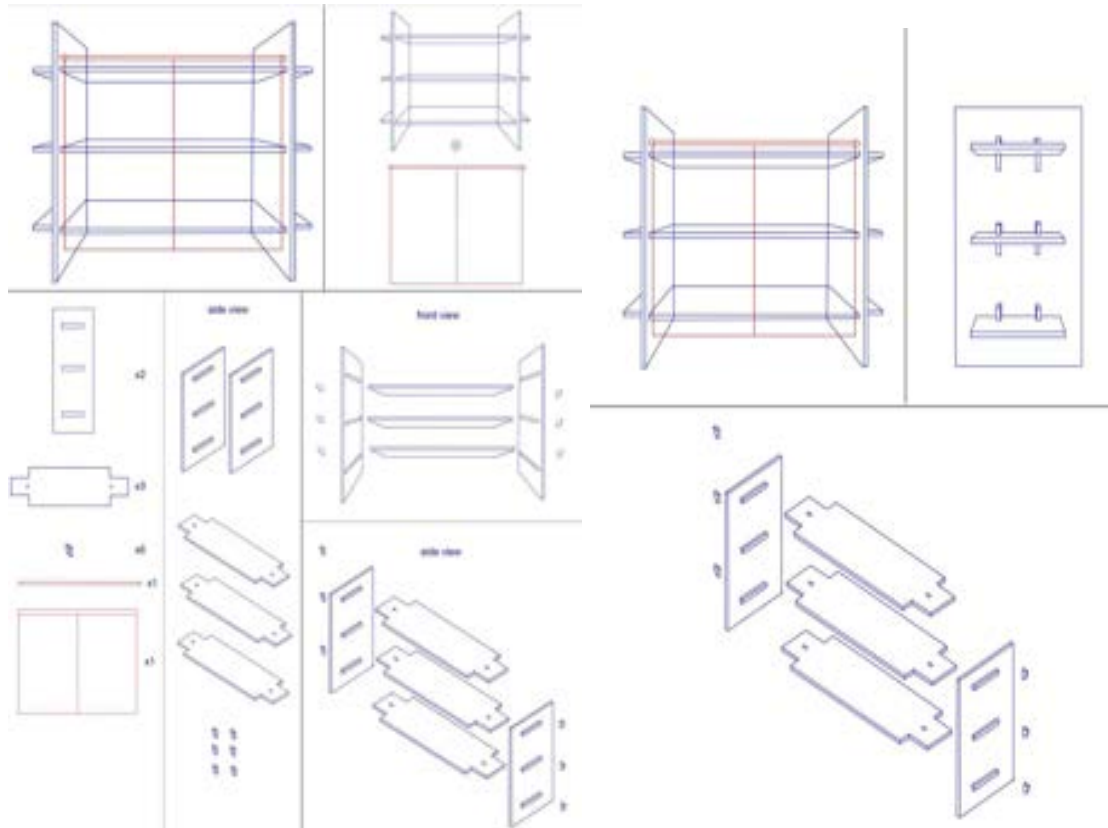
3. Entrepreneurial Spirit and Innovation

Students developed a sense of entrepreneurship and innovation through design, construction, and innovation. In this way, they could use new actualizations and embrace themselves in roles that meant they could plan, design, and implement their initiatives – as in the start-up process from idea to formation.

-Students benefited from the issue raised by the workshop: to hone in on the creation process and be mindful of everyone's input (and how they think). Through this variable of ownership and positive recognition, which entailed seeing their ideas materialize, they were more encouraged to engage in other entrepreneurial activities (Ciufu et al., 2024).

Sustainable Design Blueprint

The final tangible outcome resulting from the workshop's completion was the incorporation of sustainable design features, integrating the students' concept of abstract art into a chair that was not only practical but aesthetically fashionable. It is not a pilot model, and it is a model that can be used between students in any part of the world, therefore stressing the significance of incorporating art and design into the learning process in all the curricula of schools (Csikszentmihalyi, 1975). The idea was inspired by the success of IKEA and the invitation to consumers to DIY furniture. Why not bring that same concept to education and have the artists provide workshops to engage and bring that design to life? In addition to creativity and practical knowledge development, it empowers learners regarding environmental issues (Ciufu et al., 2024). Sometimes, students are allowed to use environmentally adverse consumables and processes to implement their ideas but are occasionally discouraged from doing so and minimizing paper usage as it affects the environment.



Market Research: Enhancing Hands-on Learning

By performing the practical tests, the students can practice what they learn, meaning they can grasp well and never forget. Moreover, the entrepreneurial view on the project contributed to improving students' innovative and self-directed opinions on the work (Bickel et al., 2023). Also, art-making positively affected their mental health and concentration. It was practically therapeutic for them, allowing for the breakthrough in the piece, simultaneously for their feelings, and making them focus. Such an approach enhances academic results and the students' prosperity and self-realization (Carlotto, 2024).

Conclusion

As for the Abstract Bookshelf Project's characteristics and capabilities, it should be noted that this concept incorporates several useful features in harmony with the principles of forming a progressive education environment. It satisfies seven of the eight-course objectives of envisioning an environment that supports creativity, promoting and maintaining physical and psychological health among learners, and the desire to produce entrepreneurial-minded learners. Thus, involving abstract and three-dimensional art in the educational process allows for the implementation of the principle of active and experience-based learning. The pilot performance at the Sparkling Mindz School exhibited the possibility of positive changes in the learning environments and forms of education. Students absorb the subject, find their way to own the work, and are satisfied with turning their concepts into something tangible.

In addition, the contributions of rubric partner schools and nonprofit organizations dedicated to the importance of art and environmental sustainability are vital in expanding it.

Learning at such significant levels would help deal with the widespread adoption of such innovative practices in education, thus bringing about systems transformation regarding incorporating art and design in learning. The goals associated with the initiative to be sustainable, minimalistic, and focused on the community also correlate with education concepts that look to raise responsible and mindful citizens of the world. Hence, the Abstract Bookshelf Project is not a project but a movement towards changing the education paradigm for learners' benefit and tackling the contemporary world.

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The American Dream: A Story of Pursuing and Seizing Opportunities By Yujie B. Zhang

In 1967, Dennis Muhlstein, a third-generation German immigrant, served in the US Air Force during the Vietnam War to demonstrate his devotion to his country. A few years later, the Texas native became a NASA engineer. There, he met a South Vietnamese refugee who led him to believe that the US involvement in the Vietnam War was driven by greedy US politicians for their personal gain. Muhlstein's interview shows the common theme of how personal experiences can change initial perspectives for the worse or better. Despite his opinion on the US involvement in Vietnam, Muhlstein believes that communism is bad as it restricts freedom, and the United States is the opposite-- representing freedom around the world. Another concept evident in Muhlstein's interview is his unwavering, hopeful patriotism due to his satisfaction with the civil and economic liberties given in this country. Muhlstein feels he must succeed since his ancestors migrated here to gain freedom and have a better life. After getting a family, Muhlstein started his own company, accomplishing his life-long goal. Dennis Muhlstein shows that with hard work, education and career goals can be achieved, revealing the idea that meritocracy is the center of the American Dream.

Dennis Muhlstein went through rigorous education and pursued several careers throughout his life to chase his dream of mechanical engineering. Muhlstein was "born in Hallettsville, Texas August 7th, 1948, and was raised on a farm near Schulenburg, Texas."i His family owned a blacksmith shop that "manufactured a number of tools... such as a grain thrasher, concrete fence posts, and a unique rolling pin."ii Muhlstein "attended Hallettsville high school and in tenth grade transferred to Schulenburg Bishop Forest High."iii From a young age, Muhlstein's interest was not in farming but in mechanical electrical due to the influence from his aunt who manufactured model airplanes. This set the direction for his future education and career pursuits. At 17, Muhlstein studied studiously at the US air force electronic school for a year and went on to take assignments during the Vietnam War. "After a 4-year stint in the air force," Muhlstein moved to California and pursued a degree in mechanical engineering at UCLA. Then, he worked "at the NASA jet propulsion laboratory in California [for]...the Viking Project for Optical reconstruction of returned imagery from Mars."iv Later on, Muhlstein left his job at NASA and settled down in Austin after getting "married to Veronica and... [having] two daughters."v He started a business and worked in the University of Texas in Austin for internet engineering before retiring. Muhlstein succeeded in achieving his interest and goal-- mechanical electrical-- by working hard at school and having numerous careers.

Muhlstein's experiences with immigration, the air force, and NASA exemplify how opinions can be overcome by hard work and shaped by personal encounters. Muhlstein's "grandfather came from the German Czech border in 1892 and settled in Hackberry, Texas."vi His grandfather was not socially accepted in the neighborhood, but through his grandfather's house-building skills, "everyone realized his talent, and the barriers were broken."vii The neighbors accepted the racial difference after noticing the new skillset his grandfather added to the community. During the Vietnam War, Muhlstein served in the Air Force bases located in

“Tachikawa and Yokota, Japan, and Laos.”^{viii} After, he went to NASA where he “sponsored Bi Think, a South Vietnamese refugee who was a radio host that read the names of the deceased North Vietnamese [people] across North Vietnam as a propaganda tool.”^{ix} Through these two experiences, Muhlstein realized “that the Vietnam War was a politically and economically driven action by our own politicians.”^x He claims Lyndon B. Johnson supported the war because it was a profitable business and thinks that John F. Kennedy wanting less US involvement in Vietnam was not true. Muhlstein’s family history shows the town’s acceptance of his ancestors while his air force and South Vietnam Refugee encounter demonstrate why he changed his mind set to believe US is the motor of the Vietnam War.

Muhlstein's immigrant viewpoint and Vietnam War experience are supported by historical sources, and his opinions regarding the Vietnam war are verified later on. Muhlstein’s grandfather was an immigrant “who arrived from 1880 to 1920 during the Age of Mass Migration... from Southern and Eastern Europe.”^{xi} His grandfather overcame the barrier of being not socially accepted by bringing his housebuilding and blacksmithing skills which reflects Charles Hirschman’s research “that shows that most immigrants do assimilate...and that immigration has net positive impacts on American...society.”^{xii} Unlike Muhlstein’s opinions that the Vietnam War stemmed from American presidents, history claims US involvement was due to the “fear that voters would not forgive them for ‘losing’ [the war].”^{xiii} Eric Foner’s *Give Me Liberty* states that “Kennedy questioned ‘the wisdom of involvement in Vietnam’”^{xiv} which Muhlstein believes is also false. The convictions Muhlstein makes might prove to be true since, during Carter’s administration, they blamed the “administrations of Lyndon B. Johnson... for pursuing secretive governmental decision... that excluded the American people and then misled them ‘with false statements and sometimes outright lies.’”^{xv} Using historical resources, Muhlstein’s encounter and opinion on the Vietnam War proved to be valid.

Despite noting the shortcomings in America’s immigration policies, Muhlstein shows aspiration and dedication to his country. Muhlstein says “, immigration in this country has always been a gateway for free thinkers and the freedom to work, dream your dreams and provide a great life for your family.”^{xvi} His opinions mirror the American Dream, however, he believes “our lack of current immigration policies is not promoting this goal.”^{xvii} Muhlstein thinks the complicated screening process in America is unnecessary since immigrants come here to seek education and job opportunities. Reflecting on his life, Muhlstein is satisfied as he “always wanted to have my own business and work in technology”^{xviii} which he succeeded in doing so. He notes that “plans change along the way as the family grows [and] along with the shift in the economy.”^{xix} Muhlstein believed that America is changing a lot, especially with the rising technology economy. He ended the interview by stating, “I think America will remain a great country,”^{xx} showing his high hopes for his country. Muhlstein believes America’s immigration policies need to be more liberal but otherwise is satisfied because of the many individual rights the country provides.

I concur with Muhlstein's opinions regarding the lack of immigrant liberties and the idea that meritocracy plays a central part in America. I believe America's immigration policies aren't sufficient. An example is when Trump's administration in 2018 began "removing young children from the custody of parents who had come to...seeking asylum."^{xxi} Also, "Alabama...[made] it a crime for illegal immigrants to apply for a job and for anyone to transport them, even to a church or hospital."^{xxii} Immigrants come to the US seeking a better life and to escape communism which, as Muhlstein states, "is real and inhibits one from free thought."^{xxiii} I think immigrants, even illegal, should be given the opportunity to start a new life in the US, and the current system is not allowing that. I believe Muhlstein's "immigrant influenced background belief... that you must succeed because your parents wanted you to have a better life than they had..."^{xxiv} is a reality in America-- future generations of immigrants feel the need to work hard and succeed. Additionally, a reason contributing to their success is the "greater openness to hiring...on the basis of merit has become an integral part of many American institutions..."^{xxv} More and more, American society for looking talent and skill rather than race and status while hiring. I agree with Muhlstein on how immigrant policies should be more open and that hard work is a central part in earning success due to his life and secondary resources.

Muhlstein's interview exemplifies the diligence required on the journey towards success. To achieve his one dream of pursuing mechanical engineering, Muhlstein's life deviated in many directions' education and careerwise. The theme of changing perspectives is shown again when Muhlstein's family is accepted in their new neighborhood and when Muhlstein, through his air force and Bi Thinh encounter, thinks that the US is the driving factor of the Vietnam War. From a historical perspective, his personal experience regarding immigrants and the Vietnam War is backed by secondary resources, and his attitudes towards the US involvement in the Vietnam War are proven to be evident later on. In his legacy, Muhlstein expresses his dissatisfaction with the current immigration policy, yet he still shows confidence in America to continue its glory since, in his opinion, the US is a country of freedom. I agree with Muhlstein's opinion that there should be greater openness in immigrant policies and that meritocracy is key in America which is proven by his career successes that are achieved through hard work and dedication. Through Muhlstein's interview, it is demonstrated that the American purpose is to aid people on their journey towards their dreams, and, with the addition of individual effort, success can be achieved.

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Existentialism in Dostoevsky's *Notes from Underground* and Kafka's *The Metamorphosis* by Zehan Pan

INTRODUCTION

“God is dead,” the proclamation of German philosopher Friedrich Nietzsche (1844-1900) appeared in his work "The Gay Science" (*Die fröhliche Wissenschaft*) and "Thus Spoke Zarathustra" (Also Sprach Zarathustra), embodied his emphasis on individualism and humanism as well. Many thinkers believe humans are capable of resolving their own issues and exploring their unique ways of living in the world without the help of some greater power. With the influence of pioneers like Nietzsche, an intellectual movement emerged after the dark ages of modern history, World War II, rooted in recovering hope and freedom and rediscovering the meaning and beauty of life – namely *existentialism*.

Jean-Paul Sartre (1905-1980) was one of the first influential existentialists. In his work *Existentialism and Humanism*, Sartre introduces his understanding of human beings and how they should find a way of living. He highlights the significance of humans being active and responsible for their choices and behavior. Moreover, humans need to be conscious of making those choices for their future. In many situations, the choices are inescapable and inevitable.

Due to its foundation in individualism and humanism, existentialism indeed supports a special status for humans and their potential. Therefore, the way humans live is distinctly different compared to other animals. As Sartre emphasized *existence precedes essence*—and to quote Sarah Bakewell's *At the Existentialist Cafe* "...having found myself thrown into the world, I go on to create my own definition (or nature, or essence), in a way that never happens with other objects or life forms" (6). In order for us to define ourselves and consider the authenticity in our way of living, we have to make choices.

Consequently, anxiety arises from an abundance of freedom, as Danish philosopher Soren Kierkegaard (1813-1855) stated, “Anxiety is the dizziness of freedom.” What kind of choice to make, what rules to follow, what kind of human beings to be in the future—these are uniquely human preoccupations. Even if a person proceeds down a certain path and is already taking the responsibility for making that choice, what can be guaranteed? Existentialists have offered a distinctive way to respond to these questions—making authentic choices.

Authenticity is an essential tenet of existentialist literature. The authenticity of an action is based on an individual's situation to make decisions and undertake responsibilities. No one else should force or forbid an individual to make choices because no person can ever fully understand another person's situation. People must be responsible for making their own choices instead of following others, because what others do does not reflect whether it is suitable for a particular individual to act similarly, and others are not responsible for the consequences of the decision being made. Just as Nietzsche explicitly rejects religion, thinkers like him also reject any patterns, trends, or systems that forbid one from being unique and acting according to their authentic individual situation, since human lives should not be predictable and calculated.

Otherwise, people start to be repetitive and lose their dynamic values, becoming similar to machines that function rigidly.

During the intellectual movement of the existentialist movement, many thinkers considered it to be an encouraging and innovative way of living. Among the existentialist works, *Notes from Underground* by Fyodor Dostoevsky and *The Metamorphosis* by Franz Kafka illustrate and emphasize the central concepts of existentialism that are closely related to society and daily life.

NOTES FROM THE UNDERGROUND

Notes from Underground, a novella by Russian writer Fyodor Dostoevsky, delineates the confession of a retired civil servant, a sick man who represents Dostoevsky's interpretation of the human condition, by revealing his unstable state of mind as he introduces numerous self-conflicting perspectives and shares his dark insights into the problems of mankind. In addition, many of his contradictory opinions coincide with existential views, as they both provide a distinctive view of how humans should live their lives.

Notes from Underground explores the impact of consciousness on existence. Dostoevsky's "Underground Man" states "...to be too conscious is an illness – a real thorough-going illness" (4). One of the impacts of consciousness on the human condition is anxiety. After experiencing enjoyment and satisfaction, we continue to seek states of fulfillment. However, the process of searching for these desirable goals requires freedom, the freedom that enables us to think authentically. What's more, operating autonomously is difficult. In the process of searching for an authentic solution to the question of how to act, we are led down established paths that are suggested by others. Thus, there is no motivation or opportunity to explore decision-making or establish authenticity. However, by restricting ourselves to easy paths, we become anxious and dread our future because it is unpredictable and unescapable.

The anxiety born of consciousness also stems from the fact that we must suffer in order to reflect on the existence of failure, sickness, and other negative consequences that arise from taking action. Dostoevsky's Underground Man notes, "Does not man...love something besides well-beings? Perhaps he is just as fond of suffering?" (30). To endure the necessary anxiety of consciousness is to suffer the human condition. If humans are making authentic choices that separate them from the normal and the positive, suffering is inevitable. Furthermore, Dostoevsky extends his conditions for existentialist authenticity when he rejects laws of nature and implicitly religion. The Underground Man states "a man if necessary is ready to act in opposition to all laws...in opposition to all those excellent and useful things if only he can attain that fundamental, most advantageous advantage which is dearer to him than all" (Dostoevsky 19). Although he was a Christian, he believed that man had the answer. When we are looking for our own ways of existence, it is necessary to reject laws of nature and religion, as they are ultimately established paths that undermine human possibility.

THE METAMORPHOSIS

In *The Metamorphosis*, Kafka describes the character Gregor Samsa's transformation into a gigantic insect and the following consequences the family faced. Kafka provides vivid images with profound details for the audience to illustrate extensive universal concepts and societal problems. Similarly, many of Samsa's interpretations of humanities echo the principles of existentialism.

One essential theme of existentialism is properly demonstrated throughout the entire story, in which everyone is required to look for their own solutions under certain inescapable situations and be responsible for the consequences they have to face. Samsa, before his metamorphosis, was a salesman who worked hard to get his family out of debt. When his family is in financial trouble, he chooses to sacrifice and compromise, a suitable solution for him and his family. His confession makes clear that he dislikes his "exhausting" and "irritating" work (89). Despite all the complaints, his instinctual reaction to his body physically losing human attributes is to explain the situation to his boss in an effort to keep his job. He is determined to take responsibility for his fate. He remains focused on saving money to enhance their quality of life. He still desires to send his beloved sister to conservatory where she can be rewarded for her violin talents. Samsa is determined to encounter each new and bizarre insect-inspired difficulty with his human efforts, working as diligently as he has without pause for the last five years, with an eye to another five years, even without hope that his hard work will pay off.

Kafka further explores the significance of making our own decisions rather than waiting for outside aid. When Samsa loses the ability to walk on two feet, he has to learn to crawl with his many tiny legs. Suddenly, all his previous furniture that evoked sweet memories became impediments in his way, eventually becoming covered by dust. His mother and sister decide to clear out his room for him, so he can move freely, but Samsa becomes upset, worried that as his cherished items disappear, his hope for recovery will diminish alongside them. Furniture and objects made to support the human body represent Samsa's human identity and existence. As he climbs to protect a picture on a wall, his last hope of recovering, he demonstrates his disapproval of his family implementing an unsuitable solution for him instead of letting him make an authentic decision. Existentialism suggests that we are born to find the meaning of our own lives, our own ways of living, and our own solutions when we are separated from our chosen path. Without such freedom, we are but insects, like Samsa, who have lost the privilege to explore and dominate their own environment to their own ends.

The title *The Metamorphosis* also pays tribute to an essential theme in existentialism: personal growth and transformation. According to the Oxford Dictionary, *metamorphosis* refers to the process of transformation from an immature form to an adult form in two or more distinct stages. The example of butterfly is commonly brought up as an example. A mature butterfly encounters four stages of transformation: egg, larva, pupa, and adult. In each stage, the insect faces different obstacles as it grows and develops. Metaphorically speaking, humans have similar stages of life where they face challenges, overcome difficulties and celebrate achievements, all for one ultimate goal – pursuing a better life for themselves. In the story of his metamorphosis, Samsa becomes dehumanized and alienated from his family, and he eventually loses hope in and

control over his life. However, Samsa is not the only one who changes: his father starts to work again and treats insect-Samsa harshly; his mother also has to work and becomes very sensitive and weak; his beloved sister, who provides food for him in the early stages of his transformation, eventually proposes to get rid of “it”. In *The Metamorphosis*, the changes do not take characters from a bad state to a good one—the direction of their fortune is reversed. People become more selfish and merciless. Those people are responsible for undertaking their choices and making changes of their own, whether positive or not.

CONNECTING THEMES

Since both works embody the themes of existentialism, similar concepts are shared by the authors and existentialists. One particular point that is common in both texts is that while Dostoevsky highlights the uniqueness and potential of human beings, Kafka holds an identical view when he portrays the story, indirectly showing the value and significance of attaining human attributes when Samsa discovers his inability to speak and act. Dostoevsky suggests that a man would sacrifice and suffer “only to gain his point”, which marks “his privilege, the primary distinction between him and other animals” (27). He highly praises the special nature of mankind and the fact that a man would challenge the laws of nature just to fulfill his needs. He makes a clear distinction between human and other animals; humans are conscious of what they try to achieve, and also aware of this consciousness when they think freely—animals are unlikely to experience the same consciousness, as they simply feel what is imperative to do without the need for reasons and without the awareness of inhabiting consciousness. Due to this, Dostoevsky believes “for in any circumstances it preserves for us what is most precious and most important – that is, our personality, our individuality...maintain that this really is the most precious thing for mankind. (25)” This precious uniqueness enables humans to think freely and act according to their minds without rationality and restriction.

Kafka depicts a similar version of the human condition; however, he does so in a contrasting perspective. Samsa was once able to accomplish his goals, whether paying debts for family, raising tuition for his sister, and more. Samsa, when he was still a man, had the ability to judge freely. He was free to behave as he intended. Once he is transformed into an insect physically, even though he can think with a human mind, he is physically unable to fulfill his intentions. Kafka illustrates the uniqueness of human beings with an emphasis on the power of physicality and its contribution to this uniqueness. If a man like Samsa has human intelligence but is transformed into an insect, he cannot be entirely free due to his physical condition; if a human has no intelligence and judgment and only acts according to defined rules and restrictions, he can not be entirely free due to his mental condition.

When discussing mental freedom and breaking the boundaries of normality, both texts criticize the predictable and radical systems society has adopted to restrain human freedom and worthiness. Dostoevsky points out that “... man has such a predilection for systems and abstract deductions that he is ready to distort the truth intentionally, he is ready to deny the evidence of his senses only to justify his logic” (20). If we inherently believed in certain laws, we would not

be able to trust our actual feelings and experience. As Dostoevsky also points out, “we have only to discover these laws of nature, and man will no longer have to answer for his actions and life will become exceedingly easy for him...in which everything will be so clearly calculated and explained that there will be no more incidents or adventures in the world” (20-21). We eventually become dull and lazy without constantly having intellectual activities such as questioning and challenging the existing modalities if, in light of existing experiments and equations, we are born with solutions. Our minds and logics are restricted, and incredulity and disbelief emerge between our previous understanding and actual experience.

Dostoevsky concludes that “... every possible answer to it will be provided...everything will be extraordinarily rational...boredom may lead you to anything... (22)” Once life is predictable, boredom arises and the value of human life is reduced. Humans no longer carry the responsibility and risk of dominating their lives. They eventually become worthless, just like Samsa in *The Metamorphosis*. Prior to his metamorphosis, Samsa is just the kind of person whose future is predictable and determined. He works relentlessly to pay off family debt and is turning into a machine. Since machines have no judgments, they function repetitively and reliably. Samsa, as he works like a machine, is gradually losing his intellect and freedom, as he has no choice for his future and actions. Despite years of hard work, his value decreases to such an extent that his boss fires him with no sympathy, as if he was just a misplaced screw on the factory floor. Therefore, as both thinkers suggested, humans create their values when they explore the meaning and the way of living in their own way, instead of following norms and trends that are likely to obstruct and skew their growth and value.

A critical extension of this philosophy makes clear that life is not certain and man can not be defined. As the Underground Man speaks, his words are conflicting and constantly reject his previous thoughts; Samsa was so exhausted from work, the next day he suddenly found himself dehumanized with no precognition. Because life itself is unpredictable, humans are necessarily undefined. Definitions are offered to us by others to make us feel concrete and to stabilize facts and objects. Since humans are constantly changing, they cannot be defined by certain features, labels, or identities. Dostoevsky has offered an explanation for this fact: “I don’t wish to be hampered by any restrictions in the compilation of my notes. I shall not attempt any system or method. I will jot things down as I remember them” (34-35). From the style of writing he applies, we can infer his understanding of this changing nature of mankind. If his work was restricted to a certain tone or writing method, the message would not have been so freely and effectively conveyed to readers. As is writing, so are humans. If they are not bound to changes, they produce freely and authentically. Therefore, the process of constant evolution defies definition and restriction in order for people to achieve their full potential.

These two outstanding works vividly illustrate the internal and external conflicts faced by each of us in our search for meaning and authenticity. They depict the central themes of existentialism: freedom, anxiety, responsibility, and authenticity. By portraying characters who confront the harsh realities of existence, Dostoevsky and Kafka contribute to the existentialist discourse on what it means to be human in an often indifferent and irrational world.

Because of the uniqueness of human nature, humans are endowed with the consciousness and freedom for decision making. However, it does come with a catch. That is, the anxiety and responsibility that humans cannot escape. Nevertheless, existentialism provides an antidote. Authenticity and transformation that separate us from tradition will allow us to feel confidence when difficulty arises in our quest for human fulfillment.

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The Effect of Temperature on the Output Intensity of DNA Boolean OR Logic Circuits By Wali Hasan^a and Andrea C. Bardales^b

Abstract

Currently, researchers are exploring DNA computational capabilities to analyze biological markers, especially those that implicate cancer and other diseases. One of the most advanced technologies uses DNA strands that form DNA 4-way (4J) junction structures as a high output. The 4J structure can be bound by a molecular beacon (MB) probe to produce easily detectable fluorescent signals. This study investigates the response of the 4J at different temperatures to identify the optimal temperature for producing a high single output. We explored two-input DNA OR logic circuits, which produce high output in the presence of either one or both inputs. The gates had detectable signals in the 15-35 °C range, with the maximum at 25 °C. This study opens the possibility of using DNA OR circuits at room temperature for convenient analysis of biological markers, including detecting cancer-related microRNA.

Introduction

Approximately 2 million people will be diagnosed with cancer in the United States in 2024 and 611,720 people will die of cancer (“Common Cancer Sites”). According to Vertex Pharmaceuticals, many diseases directly result from nucleotide mutations (“Mutations and Genetic Diseases”). In cancer, DNA mutations permit cells to grow uncontrollably because normal suppression of cell growth is rendered defective. In the past, hybridization probes have been used to study DNA samples to explore these cancer-causing mutations (Dong). Hybridization probes are made of synthetic DNA that binds to a DNA or RNA analyte to identify, study, and quantify it (Kolpashchikov 2019). These probes have existed for decades, yet many need to be more efficient, specific, and less expensive. More importantly, they cannot make calculated decisions based on multiple inputs at once. In contrast, DNA logic gates, an innovative probe, can perform computational processes like a computer (Kolpashchikov 2019). For example, if the probe detects the correct input and outputs a “yes” signal, it could perform a set function; if it gets a “no” signal, the signal could travel in a different direction. Through further optimization to support more complex structures, we hope these DNA nano-constructions will be able to mimic modern computers on a biological scale.

The ability of electronic computers to process data and make complex decisions derives from their computer chips. Computer chips consist of “thousands of electronic logic gates [that] are integrated on the surface of a single silicon wafer” (Campbell). Logic gates on a computer chip have a specific input-output pattern described by Boolean logic. The presence of an input or output is represented by a high voltage (digital 1). The lack of an input or output is represented by a low voltage (digital 0). However, computer chips lack biological compatibility due to the nature of their material. Applying Boolean logic to DNA would be advantageous because DNA computers would be able to interact with biological components. Therefore, DNA logic gates

may provide a novel hybridization probe that could accurately make decisions, such as cleaving cancerous RNA strands, based on nucleotide inputs (Nedorezova).

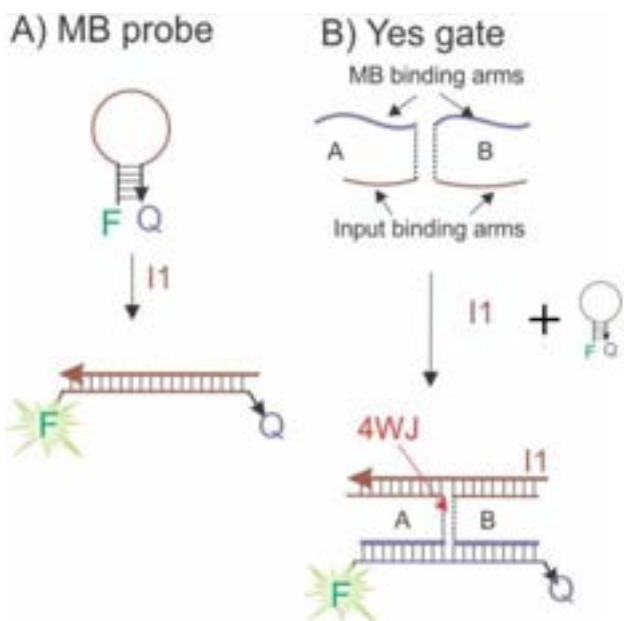


Figure 1. **A)** Molecular Beacon (MB) Probe that produces fluorescence upon binding to complementary nucleic acid sequence. **B)** A 4WJ YES gate with input and MB binding arms. In the presence of input I1, strands A and B hybridize to the MB (Kolpashchikov 2022).

Previously, Kolpashchikov et al developed a four-way junction (4WJ) YES gate, which produces a signal if and only if a specific input is present (Kolpashchikov 2022). These probes are made of a molecular beacon and two oligonucleotides. When the analyte binds to the YES gate, the molecular beacon that is also attached opens which results in an increase of fluorescence. The efficiency of the gates is measured concerning their signal-to-background (S/B) ratio, which is the difference between the fluorescence from input present samples and fluorescence from molecular beacon probe control samples divided by the difference between the fluorescence from input present samples and fluorescence from input absent samples (Equation 1).

$$S/B = \frac{F_{Input\ Present} - F_{MB}}{F_{Input\ Absent} - F_{MB}} \quad \text{Equation (1)}$$

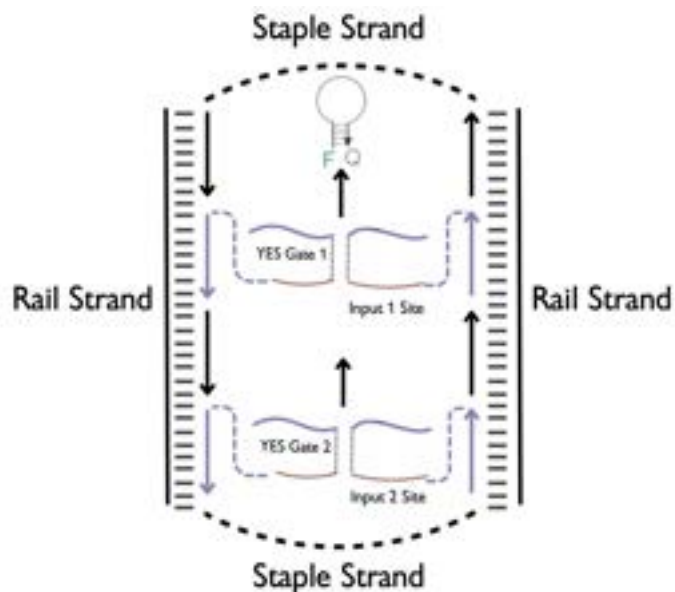


Figure 2. The design of an OR logic circuit with its strands localized within a DNA Chip, composed of two communicating YES gates and bound to the DNA scaffold (DNA chip) made of two rail strands and two staple strands for efficient inter-gate communication.

The logic circuit that this paper studies is a DNA OR circuit (Fig. 2). This OR logic circuit is a combination of two YES gates. When YES Gate 2 binds to its input, it is directed to communicate and bind to YES Gate 1 which consecutively opens the molecular beacon to separate the fluorophore from the quencher. When YES Gate 1's input is bound to its YES gate, it allows the opening of the MB probe, producing high fluorescence. Therefore, the presence of only the first input would theoretically produce a greater fluorescence output than the presence of only the second because there would be fewer total hybridization/binding events required for the opening of the molecular beacon probe.

To increase the efficacy of these logic gates, we hybridize the gates into a DNA scaffold (named here DNA chip), which may allow greater inter-gate communication because the DNA chip localizes the strands so that the four-way junction is more stable (Gerasimova). However, as a greater number of strands become interlinked, binding efficacy decreases. Solution conditions could increase or decrease binding efficacy because of the effects salt concentration and temperature have on DNA. Because the change in entropy is negative during the hybridization of two oligonucleotides, increasing the solution temperature will theoretically decrease the binding efficacy of the probe. In the equation, $\Delta G = \Delta H - T\Delta S$, when the change in entropy is negative and temperature increases, Gibbs free energy also increases. Decreasing temperature would therefore increase binding efficacy by decreasing the system's free energy (Zhang). Therefore, the purpose of this paper is to determine the temperature conditions that maximize the binding efficiency of DNA Boolean logic gates.

Methodology

Scaffold Strands	Sequence
Rail 4A2	CCT ATC GTG TT TTG TCG CTGA CCA TC GTA TCG CTT CGT CTATG
Rail 4B2	CTGAG TGAAT GAG CT CTA CA C TGC AGT ACC AC CGT TAG TCA
R11X2	ATTCA CTCAG/iSp18//iSp18/CATAG ACG AAG
Circuit Strands	
XA21	TC TAT TG/iSp18/TCT GAT AAG CTA/iSp18/CGATAC GATGG
XA221	TTA TCA GA/iSp18/A GAC AAT GTA GC/iSp18/TCAG CGA CAA
XB21	AGTAG AGCTC/iSp18/TCAA CAT CAG/iSp18/TAT GTT AACG
XB221	GGT ACT GCA G/iSp18/GAAAC CCA GC/iSp18/CTG ATG TT
Input Strands	
Input 1 (miR21)	UAG CUU AUC AGA CUG AUG UUGA
Input 2 (miR221)	AGC UAC AUU GUC UGC UGG GUUUC

Table 1. Sequences of OR Circuit, Scaffold, and Input Strands. The table displays all the nucleotide sequences of the component strands of the OR circuit, scaffold, and input strands.

Preparation of a DNA OR Circuit Scaffold

A 200-nM DNA scaffold master mix using Rail 4A2 strands, Rail 4B2 strands, R11X2 strands, R4X strands, 4x buffer (50 mM Tris HCL pH 7.4 and 50 mM MgCl₂), and DNA-grade H₂O was prepared and incubated for 15 minutes. XA21 strands, XA221 strands, XB21 strands, and XB221 strands were then added for a final concentration of 200 nM and incubated again for 15 minutes.

Preparation of the OR Circuit and MB Master Mix

A 1.7-mL centrifuge tube was labeled OR gate master mix. The presumed total volume was 550 μ L. DNA gates were then added for a final concentration of 150 nM. MB was also added for a final concentration of 75 nM. The tube was then centrifuged and vortexed.

Preparation of Molecular Beacon (MB) Control Master Mix

A 300- μ L solution containing 75 nM UMB, 1.5x Buffer, and DNA-grade H₂O in a 1.7-mL centrifuge tube labeled MB (molecular beacon) master mix was prepared. The tube was then centrifuged and vortexed.

Preparation of Molecular Beacon (MB) Control Test Tubes

Three 1.7-mL centrifuge tubes were labeled MB i, MB ii, and MB iii, respectively. The total volume of each was 60 μ L. Then, 40 μ L of MB control master mix was added to each of the three. 20 μ L of DNA-grade H₂O was then also added. The tubes were then centrifuged and vortexed.

Preparation of OR Gate Input Test Tubes

Four sets of three 1.7-mL centrifuge tubes were labeled ln0 i, ln0 ii, ln0 iii, ln21 i, ln21 ii, ln21 iii, ln221 i, ln221 ii, ln221 iii, both i, both ii, and both iii, respectively. The total volume of each tube was 60 μ L. 200 nM of miR21 and miR221 were added to their respective tubes. We then added forty μ L of the OR gate master mix to the solution. We added twenty μ L of DNA-grade H₂O. The tubes were then centrifuged and vortexed.

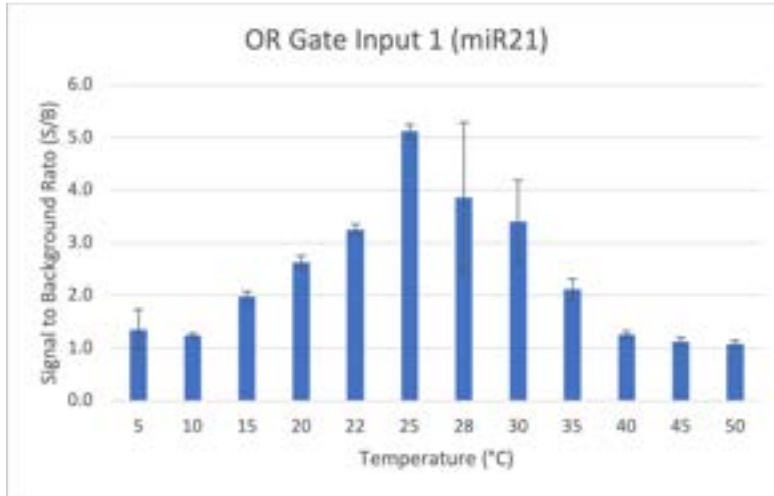
Fluorescents assays

Sample	Molecular Beacon Control	OR Circuit Without Any Inputs	OR Circuit With Only Input 1	OR Circuit With Only Input 2	OR Circuit With Both Inputs
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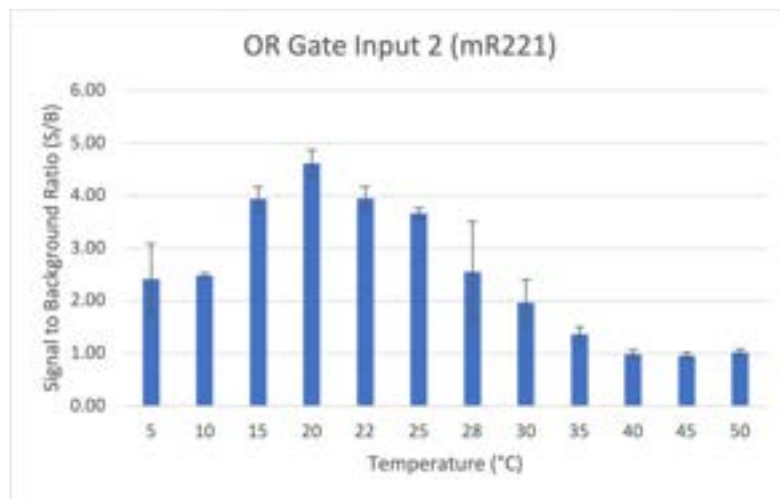
All of the samples were incubated for 20 minutes in a water bath at the temperature being tested (5, 10, 15, 20, 22, 25, 28, 30, 35, 40, 45, 50 °C). Three trials of 55 μ L of each of the above samples were pipetted into a cuvette in the same order they were prepared. The control and input samples were then tested with the fluorometer, and the fluorescence emission reading for each sample was recorded with a Perkin Elmer LS 55 Fluorescence Spectrometer. The emission wavelength was 485 nm and the excitation wavelength was 517 nm.

Results

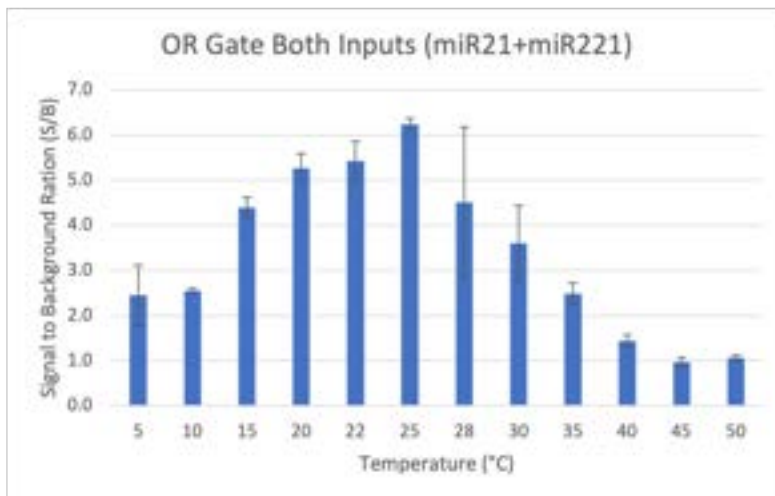
The SB ratios of the different input combinations—input 1, input 2, and both inputs—are displayed in Graphs 1, 2, and 3, respectively. The results optimizing the SB ratio are possible by changing temperature conditions. The table displays the raw fluorescence reading from each of the temperatures as well.



Graph 1. OR Circuit -Input 1 Signal to Background Ratio vs Temperature (°C). This graph depicts the S/B produced from samples containing only input 1 at different temperatures.



Graph 2. OR Circuit -Input 2 Signal to Background Ratio vs Temperature (°C). This graph depicts the S/B produced from samples containing only input 2 at different temperatures.



Graph 3. OR Circuit- Input 1 and 2 Signal to Background Ratio vs Temperature (°C). This graph depicts the S/B produced from samples containing both inputs at different temperatures.

Temperature (°C)	Molecular Beacon (F.a.u.)	Input 0 (F. a.u.)	Input 1 (F. a.u.)	Input 2 (F. a.u.)	Both (F. a.u)
5	20.63 ± 0.38	49.77 ± 13.66	67.00 ± 3.77	120.38 ± 4.99	121.79 ± 2.53
10	17.65 ± 1.00	44.52 ± 0.67	55.00 ± 1.57	110.38 ± 1.20	113.65 ± 1.37
15	14.93 ± 0.95	29.31 ± 1.33	58.15 ± 0.99	115.51 ± 2.74	128.52 ± 3.52
20	21.37 ± 0.67	24.24 ± 1.06	63.63 ± 0.87	111.98 ± 3.40	127.74 ± 5.29
22	16.96 ± 0.64	24.24 ± 0.53	78.90 ± 2.18	95.77 ± 5.27	131.36 ± 10.27
25	20.34 ± 0.20	29.48 ± 0.60	151.06 ± 2.31	108.18 ± 2.17	183.85 ± 0.72
28	27.35 ± 7.33	31.25 ± 11.52	120.50 ± 0.86	79.99 ± 4.02	141.02 ± 3.09
30	18.48 ± 0.26	16.64 ± 2.73	108.15 ± 4.42	49.54 ± 1.02	117.76 ± 16.21
40	15.97 ± 0.51	16.36 ± 0.89	20.64 ± 0.37	16.16 ± 0.86	23.52 ± 1.74
45	15.07 ± 0.14	17.08 ± 0.86	19.20 ± 1.04	16.44 ± 0.55	16.55 ± 1.46
50	20.28 ± 0.28	21.25 ± 1.06	23.05 ± 0.83	21.75 ± 0.62	22.60 ± 0.53

Table 2. Fluorescence (F. a.u.) vs Temperature. This table depicts the average fluorescence produced from each sample at different temperatures.

Discussion

For input one and both input solutions, the optimal temperature was room temperature (25 °C). For the input two solutions, the optimal temperature was 20° C. Overall, at greater than room temperature, the probe's S/B ratio decreases, indicating that intra-gate communication is inhibited due to 4WJ complex melting as shown in all graphs. Additionally, the system's free energy most likely increases because of the hybridization's negative entropy. The S/B ratio also decreased at below room temperature, indicating that unintentional inter-gate communication occurred absent inputs as shown in all graphs. Unexpectedly, at temperatures less than room temperature, the fluorescence output of samples with only input 2 was greater than that of samples with only input 1, explaining the difference in optimal temperatures between the input conditions as shown in Graph 2 and Table 2. Conversely, at temperatures at or above room temperature, the output of input 1 samples was greater than that of input 2 samples as shown in Table 2. The probe's behavior at lower temperatures may be caused by unintentional communication between the input binding arms of the differing inputs as free energy decreases. This would prohibit communication between input 1 and its binding arms but would increase the efficacy of propagation between the binding arms of input 2 and of input 1 when input 2 is present, explaining the difference in fluorescence between the samples.

The results suggest that decreases in temperature would increase the fluorescence output produced by the presence of only input 2 but decrease the fluorescence output produced by the presence of only input 1 due to extraneous interstrand communication and decreased free energy. Future experimentation could include testing whether this trend continues with other gates such as the INHBIT and XOR circuits.

Limitations. The MB control samples' fluorescence readings often varied between each trial indicating that even accidental slight changes in temperature or other conditions during the experiments may have skewed results. Additionally, the OR logic circuits are simplistic compared to the complexity of the DNA computer that would be required to effectively conclude a diagnosis based on given biomarkers. In the future, we can sophisticate these DNA computers using chains of different logic gates with the optimized temperature and possibly salt conditions. We could also test these DNA computers on disease strands to determine their medical compatibility.

Broader Impacts. Overall, DNA computational machinery represents an essential building block for the analysis and eventual treatment of nucleotide-based diseases and cancers. This may not only provide an avenue for diagnosis but also a possible cure for a broad spectrum of diseases and other biological qualms.

ACKNOWLEDGMENTS

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Moral competence and ethical decision-making: Unraveling neural patterns in fMRI studies By Rithvik Dhara

Abstract

This literature review aims to summarize existing work on the neural correlates of MC and discuss how insights from this body of research could have far-reaching implications across various fields. Neuroimaging studies offer a unique lens to distinguish competing philosophical theories of moral reasoning. We start by describing existing paradigms used to probe and measure MC and discuss their unique strengths as well as their limitations. We then go on to summarize work localizing neural function as well as function connectivity patterns associated with moral decision-making, reasoning, and competence. We go on to explore the neural underpinnings of utilitarian versus deontological approaches and summarizing neural pathways that may favor one moral philosophy over another. This exploration not only speaks to the importance of considering neuroscientific perspectives but also engages deeply with ongoing philosophical debates.

Introduction

Human beings possess a unique capacity for making moral judgments that differentiate between right and wrong as well as ethical decisions based on societal norms. How an individual employs this capacity has been known as their "moral competence," or MC. While scientists still debate exact definitions of moral competence (Martin et al, 2023), it is often defined as involving the ability to consistently judge moral issues logically (Ma, 2012). Accordingly, this ability often requires the intertwining of cognitive and emotional processes.

In furthering understanding of MC, researchers have explored related psychological concepts including emotional intelligence in ethical decision-making. Emotional intelligence, defined as the ability to perceive, use, understand, and manage emotions (Mayer, Salovey, & Caruso, 2000), significantly contributes to moral reasoning by enabling individuals to empathize with others and assess the emotional outcomes of their actions (Mayer et al., 2000). Mayer, Salovey, and Caruso (2000) emphasize that emotional intelligence influences an individual's capacity to make ethical decisions, suggesting a link between emotional processing and moral judgment. Further, empathy, a crucial component of emotional intelligence, plays a significant role in moral competency. Decety and Cowell (2014) argue that empathy involves understanding and sharing the feelings of others, which is essential for making compassionate moral judgments (Decety & Cowell, 2014). The neural basis of empathy has been widely studied, with findings indicating activation in brain areas such as the ventromedial prefrontal cortex (VMPFC) and the insula during empathetic processing (Decety & Cowell, 2014). These areas are also implicated in moral reasoning, highlighting the interconnectedness of empathy, emotional intelligence, and moral competency and the multifaceted nature of moral competency.

Neuroimaging studies, particularly those utilizing functional magnetic resonance imaging (fMRI), have been instrumental in highlighting the potentially similarly multifaceted neural basis

of MC. For example, Jung et al.'s 2016 articles argue that their findings suggest that neural functions typically associated with both cognitive and emotional mechanisms are also implicated in moral reasoning. This study reveals consistent activation patterns during moral reasoning tasks in brain regions including the vmPFC, medial frontal cortex, and posterior cingulate cortex, which form part of the default mode network (Jung et al., 2016). Neuroimaging research may have the potential to help demonstrate the integration of cognitive and emotional processes during effective moral judgment making.

For example, a notable study by Greene et al. (2001), provides clear evidence of the integration of cognitive and emotional processes in moral judgment making. Specifically, they probed moral judgment by having participants complete two common moral dilemmas during an fMRI scan, specifically the trolley problem, described in further detail below, and the footbridge dilemma. Their findings indicate that when participants are faced with these moral dilemmas, significantly increased activation in the medial frontal gyrus, the posterior cingulate, and the bilateral angular gyrus in the moral-personal condition versus the moral-impersonal and the non-moral conditions. Further, they found that the right middle frontal gyrus and the parietal lobe were significantly less active in the moral-personal condition than in the other two conditions. The authors suggest that because they found increased activity in brain regions previously associated with emotion processing and decreased activity in brain regions previously associated with forms of cognitive control, their findings may suggest the critical involvement of both cognitive effort in making moral judgments as well as emotional reactions to the implications of their judgements.

These studies begin to show how neuroimaging can help illuminate the neural basis of relatively complex and uniquely human decision-making processes, such as MC, that involve self-reflection, abstract thought, perspective-taking, and the integration of cognitive and emotional processing. This literature review aims to summarize existing work on the neural correlates of MC and discuss how insights from this body of research could have far-reaching implications across various fields. We start by describing existing paradigms used to probe and measure MC and discuss their unique strengths as well as their limitations. We then go on to summarize work localizing neural function as well as function connectivity patterns associated with moral decision-making, reasoning, and competence. While previous research has identified brain regions implicated in moral reasoning, understanding functional connections between these regions may provide valuable insights into the neural basis of MC. Furthermore, neuroimaging studies offer a unique lens to distinguish competing philosophical theories of moral reasoning. We go on to discuss one such example, exploring the neural underpinnings of utilitarian versus deontological approaches and summarizing neural pathways that may favor one moral philosophy over another. Finally, we describe the limited existing evidence on the neural correlates of individual differences in MC and offer possible areas for future work. This exploration not only contributes to the field of neuroscience but also engages deeply with ongoing philosophical debates. By examining the interplay of brain regions and philosophical theories, we aim to shed light on the intricate workings of the human moral compass.

Understanding and Measuring Moral Competency: The Foundations and Frameworks

Moral competence (MC) is a critical type of decision-making that occurs in the context of, often high-stakes, ethical dilemmas. As such, understanding MC is critical to understanding human behavior. The ability to quantify MC has been a topic of extensive research. Below we provide a brief overview of some of the most commonly used paradigms in measuring and assessing this multidimensional construct that encompasses both moral reasoning and ethical judgments, and that requires both cognitive and emotional faculties. Specifically, we describe details of multiple prominent assessments used in the field and what aspects of moral competency it aims to evaluate and discuss the unique strengths and weaknesses of each paradigm.

One prominent approach to measuring moral competency is the Moral Competence Test (MCT), developed by Lind (2008). This assessment focuses on evaluating an individual's capacity to judge moral issues based on their understanding of justice and welfare principles, rather than relying on learned ethical rules or inclinations towards specific behavior (Lind, 2008). The MCT is a set of questions or scenarios that aim to evaluate an individual's moral competence across different dimensions and does not depend on the age of the individual. These scenarios are often designed to reflect real-world situations that individuals might encounter, allowing researchers to assess how individuals approach and resolve moral dilemmas (Lind, 2008). For example, in one scenario presented in moral competency assessments, individuals may be asked to decide whether to allocate a life-saving medication to a patient who can afford it but is less likely to benefit from it, or to a patient who cannot afford it but has a higher chance of survival. What sets this assessment apart is its utilization of a dual-aspect model to assess moral competency, and its ability to distinguish between cognitive and affective aspects of moral decision-making (Lind, 2008). As such, this approach aims to provide insights into how individuals reason about moral dilemmas and justify their judgments (Lind, 2008).

Whereas other assessments take a more developmental approach to assessing moral competency such that they aim to identify specific stages of moral development, the Defining Issues Test (DIT) proposed by Rest (1999), is grounded in Kohlberg's stages of moral development, which represents a framework that categorizes moral reasoning into different stages of development: pre-conventional, conventional, and post-conventional. This is based on the level of ethical reasoning and understanding of moral principles. The DIT distinguishes these stages by examining the reasoning behind choices in moral dilemmas (Rest, 1999). The DIT primarily assesses and focuses on the extent to which an individual uses post-conventional reasoning, which refers to a level of moral reasoning beyond societal norms and personal gain, focusing instead on universal ethical principles and values. Individuals who exhibit post-conventional reasoning prioritize justice, human rights, and ethical ideals over obedience to authority or conformity to cultural norms, reflecting a principled understanding of morality beyond personal gain or conformity to societal norms (Rest, 1999). Similar to the MCT, this assessment isn't limited to any particular age group; rather, it offers insights across various stages of life. Researchers have employed the DIT to explore moral development in youth, adolescents,

and adults, examining how moral reasoning evolves over time and in response to diverse life experiences (Rest, 1999). By encompassing a broad spectrum of age groups, both the DIT and MCT can provide an understanding of moral judgment across the lifespan while the DIT categorizes individuals MC into levels, the MCT categorizes individuals' MC based on approach.

In contrast to these assessments that measure MC regardless of age, several studies have begun to contribute to our understanding of moral development across time and different stages of life, one being Rest, Narvaez, Bebeau, and Thoma (1999), who conducted a study that found correlations between scores on the Defining Issues Test (DIT) and factors such as age, education level, and moral reasoning development. Not only did they observe that individuals with higher education levels tended to exhibit more advanced moral reasoning, consistent with Kohlberg's stages of moral development; their findings also suggested that moral reasoning tends to develop and evolve over time and is influenced by life experiences and exposure to ethical dilemmas.

While both the DIT and MCT involve participants answering questions about theoretical scenarios, other measurement tools, including the Prisoner's Dilemma, involve participation in an active task, interacting with other players, and making multiple choices and behavioral responses. For example, the Prisoner's Dilemma is a classic game theory task where two players must decide whether to cooperate or defect, leading to different payoffs depending on their choices (Rand & Nowak, 2013). This task measures aspects of moral decision-making related to cooperation, trust, and reciprocity, providing insights into social behaviors and ethical reasoning (Rand & Nowak, 2013). In the Prisoner's Dilemma, participants are typically presented with a scenario where they must choose between cooperating with the other player for mutual benefit or defecting to gain a higher individual payoff while risking the other player's outcome (Rand & Nowak, 2013). The task is often administered using a payoff matrix that outlines the possible outcomes based on each player's choice, highlighting the consequences of cooperation and defection (Rand & Nowak, 2013). Researchers analyze participants' decisions to understand their moral reasoning strategies, such as fairness, self-interest, or altruism, in competitive and cooperative settings (Rand & Nowak, 2013). The Prisoner's Dilemma is unique in its ability to capture strategic decision-making in moral contexts, highlighting the tension between self-interest and collective welfare (Rand & Nowak, 2013).

Critics argue that the Prisoner's Dilemma oversimplifies moral dilemmas by focusing solely on rational choices within a limited framework, neglecting the complexity of real-world ethical decisions (Rand & Nowak, 2013). For example, in real-life situations, individuals may consider factors like trust, relationships, long-term consequences, and societal norms when making moral judgments, which are not fully captured in the Prisoner's Dilemma task (Rand & Nowak, 2013). Additionally, the task may not account for emotional responses, empathy, or moral principles that guide individuals' decisions in moral dilemmas (Rand & Nowak, 2013). These more real-world theoretical questions have some pros because they involve more complex sensations whereas the tasks contain more authentic behavior and aren't just theoretical.

Nevertheless, the Prisoner's Dilemma remains a valuable tool for studying moral decision-making in controlled environments and understanding human behavior in competitive and cooperative interactions (Rand & Nowak, 2013).

Similarly, the Dictator Game is an economic task where one participant (the dictator) decides how to divide a sum of money with another participant (the receiver), who has no input in the decision (Engel, 2011). This task measures aspects of fairness, altruism, and empathy in economic decision-making, providing insights into prosocial behaviors and moral values (Engel, 2011). In the Dictator Game, participants are typically given control over distributing resources and are not bound by formal rules or regulations, allowing them to make decisions based on personal preferences and attitudes towards fairness (Engel, 2011). The task is often administered using computerized or paper-based simulations that simulate economic interactions and decision-making scenarios (Engel, 2011).

One aspect that makes the Dictator Game special is its ability to reveal individual attitudes towards fairness, generosity, and reciprocity in economic exchanges (Engel, 2011). For example, some participants may choose to share resources equally or altruistically, while others may prioritize self-interest or fairness based on merit or need (Engel, 2011). Researchers analyze participants' decisions and behaviors to understand their motivations, social preferences, and moral norms that influence economic decision-making (Engel, 2011). However, the Dictator Game may not fully capture complex moral reasoning as it involves simplified economic interactions and limited context, which may not reflect real-world ethical dilemmas and considerations (Engel, 2011).

The Trolley Problem presents participants with a moral dilemma where they must decide whether to divert a runaway trolley onto a track where it will kill fewer people but still result in harm (Foot, 1967). This task assesses moral reasoning regarding utilitarian versus deontological principles and highlights the conflict between maximizing overall welfare and adhering to moral rules (Foot, 1967). In the Trolley Problem, participants are typically presented with a scenario where they must choose between two morally challenging options: either taking an action that directly causes harm to save more lives (utilitarian approach) or refraining from causing harm but allowing more casualties (deontological approach) (Foot, 1967). The task is often administered using written or visual scenarios that evoke emotional responses and ethical dilemmas, prompting participants to make difficult moral judgments (Foot, 1967).

One aspect that makes the Trolley Problem special is its ability to reveal individual preferences for different moral principles and the trade-offs involved in ethical decision-making (Foot, 1967). For instance, some participants may prioritize saving more lives and minimizing harm (utilitarian perspective), while others may prioritize adhering to moral rules and avoiding direct harm (deontological perspective) (Foot, 1967). Researchers analyze participants' responses to understand their moral reasoning processes, ethical values, and cognitive biases that influence decision-making in moral dilemmas (Foot, 1967). However, the Trolley Problem has been criticized for its hypothetical nature and lack of real-world applicability, as participants'

responses may differ in actual moral dilemmas with higher stakes and personal involvement (Foot, 1967).

The Lottery Paradox is a philosophical puzzle that challenges traditional views on probability and rational belief (Kyburg, 1961). This paradox highlights the conflict between statistical reasoning and intuitive beliefs about uncertainty and chance (Kyburg, 1961). In the Lottery Paradox, participants are presented with a scenario where they must consider the probability of winning a lottery with extremely low odds (Kyburg, 1961). The task prompts participants to reflect on their beliefs and judgments regarding the likelihood of rare events and the rationality of holding certain beliefs in the face of statistical evidence (Kyburg, 1961). Researchers use the Lottery Paradox to explore how individuals reconcile statistical reasoning with intuitive beliefs about uncertainty and risk (Kyburg, 1961).

One aspect that makes the Lottery Paradox special is its ability to challenge conventional notions of rational belief and decision-making (Kyburg, 1961). For instance, participants may struggle to reconcile the statistical probability of winning a lottery with their intuitive beliefs about luck, chance, and personal expectations (Kyburg, 1961). Researchers analyze participants' responses and reasoning processes to understand how individuals navigate uncertainty, assess probabilities, and make rational judgments in uncertain situations (Kyburg, 1961). However, the Lottery Paradox has been critiqued for its abstract nature and limited applicability to real-world decision-making, as it focuses on extreme cases of uncertainty that may not fully capture everyday reasoning and beliefs (Kyburg, 1961).

While critiques of moral tests often focus on their hypothetical nature and limited real-world applicability, it's crucial to acknowledge the purpose of these tests in isolating specific aspects of moral decision-making. Real-world ethical dilemmas are incredibly complex, influenced by numerous variables and contextual factors that can muddy the understanding of underlying moral principles. By simplifying scenarios and controlling for extraneous variables, moral tests provide a controlled environment for studying fundamental moral reasoning processes. In this context, the perceived drawback of real-world applicability becomes a necessary trade-off in scientific inquiry, allowing researchers to dissect and analyze intricate moral components with greater clarity.

Incorporating these thought experiments into the study of moral competency illuminates the multifaceted nature of ethical decision-making. They not only serve as tools for probing the principles underlying moral judgments but can also be used in neuroimaging studies to offer insights into the neural mechanisms that govern such decisions. Overall, by examining how individuals navigate these dilemmas, researchers gain a deeper understanding of the cognitive and emotional components of moral reasoning, the development of moral principles, and the impact of societal norms on ethical behavior.

Brain Functions Associated With Moral Competency and Moral Judgements

Recent empirical studies have sought to correlate these measures of moral competency with neurobiological underpinnings. This line of research shows the importance of integrating psychological and neuroscientific approaches to fully comprehend the complexity of moral competency. Neuroimaging studies have broadly associated brain function in various regions with MC. We summarized these functional neural correlates in the section below. Overall, this line of work helped scientists uncover the neural substrates of the complex construct of MC and its interacting high-level subcomponents. In addition, many of these social dilemmas and moral thought experiments have been employed by neuroimagers to probe brain function related to this construct.

With the aim of quantitatively summarizing brain function associated with moral processing and moral judgments, we conducted a coordinate-based, spatial meta-analysis of the term “moral” through Neurosynth (Yarkoni et al., 2011). Neurosynth is a tool that combines text-mining, meta-analysis and machine-learning techniques to generate probabilistic mappings between cognitive and neural states that can be used for a broad range of neuroimaging applications. (Yarkoni et al., 2011). The overall goal of these types of meta-analyses is to average over the inherent error associated with each brain-behavior link observed, across all studies in the existing available literature that are uploaded to the Neurosynth database, to capture the robust brain activity patterns that are *consistently* associated with a certain cognitive/behavioral construct. We utilized this software to find locations that consistently show increased activity when individuals are performing moral-related tasks in the scanner. As shown in **Figure 1**, the 87 existent neuroimaging studies in Neurosynth database that are associated with the meta-data term “moral” displayed convergent increased brain activity in the Temporal-Parietal Junction (TPJ), the Inferior Frontal Gyrus (IFG), the Bilateral Right Anterior Insula (RAI), Bilateral Amygdala (BA), the Posterior Cingulate Cortex / Precuneus (PCC), and a cluster in the Ventromedial Prefrontal Cortex (vmPFC) that extends to the DLPFC. This indicates that across studies (with varying samples and methodologies) these regions are consistently observed during moral tasks. "Convergent activity" in neuroimaging studies refers to consistent patterns of brain activation observed across multiple studies, despite variations in sample populations, methodologies, or specific tasks.

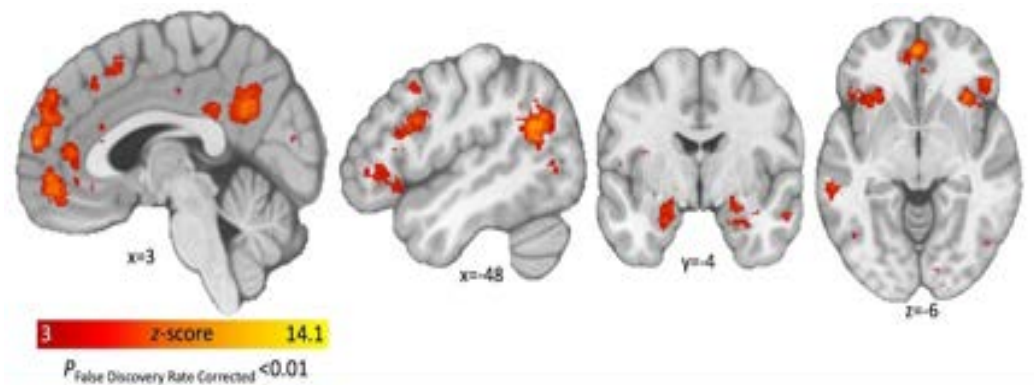


Fig 1: Brain activity consistently observed during moral processing. A NeuroSynth meta-analysis of the term “moral” displayed convergent increased brain activity across 87 studies. <https://neurosynth.org> (Yarkoni et al., 2011). Moral-related tasks appear to largely recruit activity in regions of the default mode network, including the hippocampus, as well as critical hubs in the salience network including the anterior insula and dmPFC. Finally other regions typically associated with cognitive control were also observed including the dlPFC and inferior frontal gyrus. Overall, results suggest the multifaceted nature of moral processing and recruitment of widespread higher-order cortical brain regions.

Numerous studies have identified specific brain regions associated with moral cognition, shedding light on the neural substrates of ethical decision-making (Greene et al., 2001; Moll et al., 2002; Harenski et al., 2008). The default mode network (DMN), for instance, is activated during tasks requiring self-referential thinking and moral reasoning, suggesting its role in considering the perspectives and well-being of others. Greene et al. (2004) demonstrated that moral decision-making involves a complex interplay between emotional responses, mediated by the ventromedial prefrontal cortex (VMPFC), and cognitive processing, involving areas such as the dorsolateral prefrontal cortex (DLPFC) (Greene et al., 2004). One crucial region implicated in moral reasoning is the Temporal-Parietal Junction (TPJ), which plays a role in theory of mind and perspective-taking, allowing individuals to understand the mental states of others and consider alternative viewpoints in moral dilemmas (Greene et al., 2001). fMRI studies have consistently shown increased activity in the TPJ during tasks involving moral judgment and social cognition, indicating its involvement in processing moral information (Greene et al., 2001). Additionally, the inferior frontal gyrus (IFG) has been linked to moral decision-making processes, particularly in inhibitory control and conflict resolution (Moll et al., 2002). Studies using fMRI have demonstrated activation in the IFG when individuals engage in moral reasoning tasks that require suppressing prepotent responses or resolving ethical conflicts (Moll et al., 2002). This suggests that the IFG plays a role in executive functions related to moral judgments and decision-making under conflicting values or norms (Moll et al., 2002).

The bilateral right anterior insula (RAI) is another brain region implicated in moral cognition, specifically in processing emotional responses and bodily sensations that contribute to moral judgments (Harenski et al., 2008). Neuroimaging studies have shown increased activity in the RAI during tasks involving empathy, moral emotions, and subjective feelings of moral rightness or wrongness (Harenski et al., 2008). This indicates that the RAI plays a critical role in integrating emotional and visceral cues into moral decision-making processes (Harenski et al., 2008).

Moreover, the involvement of the Bilateral Amygdala (BA) in moral cognition has been highlighted in research focusing on emotional processing and moral evaluations (Moll et al., 2002). The amygdala's role in detecting and responding to emotionally salient stimuli contributes to the affective component of moral judgments, influencing how individuals assess the moral significance of actions or events (Moll et al., 2002). fMRI studies have demonstrated amygdala activation in response to morally relevant stimuli, suggesting its contribution to the emotional processing underlying moral reasoning (Moll et al., 2002).

In summary, understanding the importance of various brain regions in moral cognition provides insights into how humans make ethical decisions. The Default Mode Network (DMN) is crucial for self-referential thinking and considering others' perspectives, highlighting its role in moral reasoning. The Ventromedial Prefrontal Cortex (VMPFC) mediates emotional responses, while the Dorsolateral Prefrontal Cortex (DLPFC) handles cognitive processing, showing the complex interplay in moral decision-making. The Temporal-Parietal Junction (TPJ) aids in theory of mind and alternative viewpoint consideration, essential for navigating moral dilemmas. The Inferior Frontal Gyrus (IFG) contributes to inhibitory control and conflict resolution in moral judgments, crucial in decision-making under conflicting values. The Bilateral Right Anterior Insula (RAI) integrates emotional cues into moral decisions, emphasizing its role in processing moral emotions. Lastly, the Bilateral Amygdala (BA) detects emotionally salient stimuli, influencing the affective component of moral evaluations and contributing to the emotional processing of moral reasoning.

Utilitarian vs. Deontological Judgements in Relation to Brain Function

The debate between utilitarian and deontological ethics has long been a central topic in moral philosophy, focusing on whether ethical judgments should prioritize maximizing overall happiness (utilitarianism) or adhering to moral principles and duties (deontology). Recent advances in neuroscience have allowed researchers to investigate the neural correlates of these distinct moral frameworks, shedding light on how different brain regions contribute to utilitarian and deontological judgments.

Utilitarianism, rooted in the principle of maximizing utility or overall well-being, often involves sacrificing individual interests for the greater good (Greene et al., 2004; Koenigs et al., 2007). Neuroimaging studies have shown that utilitarian judgments are associated with increased activation in brain regions involved in cognitive control and executive functions, such as the dorsolateral prefrontal cortex (DLPFC) and anterior cingulate cortex (ACC) (Greene et al., 2004;

Koenigs et al., 2007). These areas play a role in weighing options, evaluating consequences, and suppressing emotional responses during moral decision-making tasks (Greene et al., 2004; Koenigs et al., 2007).

Deontological ethics, on the other hand, prioritizes adherence to moral rules, principles, and duties, regardless of the consequences or outcomes (Greene et al., 2004; Mikhail, 2007). Studies have shown that deontological judgments are associated with increased activation in brain regions linked to emotional processing and moral intuition, such as the ventromedial prefrontal cortex (vmPFC) and posterior cingulate cortex (PCC) (Greene et al., 2004; Mikhail, 2007). These areas are involved in processing emotional salience, moral norms, and personal values, influencing individuals to make decisions based on moral rules rather than utility calculations (Greene et al., 2004; Mikhail, 2007).

Individual differences in moral reasoning styles can be conceptualized as more utilitarian vs. deontological judgments (Greene et al., 2004; Bartels, 2008). Traits such as empathy, cognitive empathy, moral identity, and cognitive styles influence the likelihood of adopting utilitarian or deontological frameworks (Greene et al., 2004; Bartels, 2008). For instance, individuals with high levels of cognitive empathy may lean towards utilitarian judgments, considering the overall welfare of others, while those with a strong moral identity may prioritize deontological principles, adhering to moral rules regardless of consequences (Greene et al., 2004; Bartels, 2008). The trolley problem, as mentioned before, has been used to study utilitarian vs. deontological judgments and their neural underpinnings (Greene et al., 2004; Cushman et al., 2006). Neuroimaging studies have revealed distinct patterns of brain activation during trolley problem scenarios, with utilitarian responses associated with increased activity in cognitive control regions, while deontological responses correlate with heightened emotional processing areas (Greene et al., 2004; Cushman et al., 2006).

Furthermore, cultural and contextual factors influence the prevalence of utilitarian or deontological reasoning in different societies (Greene et al., 2004; Haidt, 2007). Cross-cultural studies have revealed variations in moral judgments and ethical frameworks, reflecting diverse cultural norms and values (Greene et al., 2004; Haidt, 2007). These cultural differences in moral reasoning are mirrored in the neural correlates of utilitarian and deontological judgments, highlighting the interplay between brain function and socio-cultural influences on moral decision-making (Greene et al., 2004; Haidt, 2007). Developmental experiences and educational backgrounds also shape moral reasoning and ethical frameworks (Greene et al., 2004; Smetana, 2006). Childhood socialization, exposure to ethical dilemmas, and moral education play a role in shaping individuals' moral intuitions and decision-making processes (Greene et al., 2004; Smetana, 2006). These early experiences contribute to the development of moral values, guiding individuals towards utilitarian or deontological reasoning patterns (Greene et al., 2004; Smetana, 2006).

In conclusion, the study of utilitarian vs. deontological judgments and their neural correlates provides valuable insights into the complex interplay between cognitive processes, emotional responses, cultural influences, and ethical decision-making, contributing to a deeper

understanding of human morality and ethics. The study of utilitarian vs. deontological judgments from a neuroethical perspective raises questions about moral responsibility, free will, and the influence of brain function on ethical behavior (Greene et al., 2004; Racine et al., 2005). Neuroethics, a field at the intersection of neuroscience and ethics, explores the ethical implications of neuroscientific findings on moral decision-making (Greene et al., 2004; Racine et al., 2005). These discussions have implications for ethical decision-making in various domains, including healthcare, law, and public policy (Greene et al., 2004; Racine et al., 2005).

Future Directions

Why some individuals make different moral choices under similar circumstances is still not fully understood. This pivotal question paves the way for a deeper examination of the unique factors influencing each person's moral reasoning. Delving into the realm of individual differences in MC will shed light on the intricate web of cognitive and emotional elements that sculpt our moral landscape, offering a richer understanding of MC. Understanding these individual differences lies at the heart of understanding MC, a topic of growing interest and importance in realms ranging from psychology to legal studies.

Transitioning from a broad overview of brain regions involved in moral cognition, we now turn our focus to the nuanced realm of individual differences, which illuminate the diverse neurological details that shape each person's unique moral judgments and decision-making processes. Individual differences in moral cognition are influenced by various factors, including genetic predispositions, developmental experiences, and personality traits (Koenigs et al., 2007; Luo et al., 2015; Takahashi et al., 2014). For example, genetic studies have identified polymorphisms in genes related to neurotransmitter function, such as serotonin and dopamine, that contribute to variations in moral sensitivity and decision-making (Koenigs et al., 2007). Functional neuroimaging studies have linked these genetic variations to differences in brain activation during moral tasks, suggesting a neurobiological basis for individual differences in moral cognition (Koenigs et al., 2007). Specifically, he found that individuals with a genetic variant associated with lower serotonin function showed increased activation in the amygdala and anterior insula during moral decision-making tasks (Koenigs et al., 2007) These brain regions are commonly associated with emotional processing and empathy, suggesting that genetic differences can influence how individuals respond emotionally to moral dilemmas.

Furthermore, developmental experiences, such as upbringing, education, and cultural influences, shape moral values and reasoning abilities (Luo et al., 2015). Cross-cultural studies have revealed differences in neural responses to moral dilemmas among individuals from diverse cultural backgrounds, highlighting the impact of sociocultural factors on moral cognition (Luo et al., 2015). Specifically, individuals from different cultural backgrounds exhibited differences in how their ventromedial prefrontal cortex and temporoparietal junction responded during moral decision-making tasks (Luo et al., 2015). These findings underscore the importance of considering sociocultural context in understanding individual differences in moral judgments (Luo et al., 2015).

Personality traits also play a significant role in shaping moral decision-making processes (Takahashi et al., 2014). Traits such as empathy, conscientiousness, and moral identity have been associated with distinct patterns of brain activity during moral tasks (Takahashi et al., 2014). For instance, individuals high in empathy show greater activation in brain regions associated with emotional processing and perspective-taking when confronted with moral dilemmas involving harm to others (Takahashi et al., 2014). This suggests that individual differences in personality contribute to variability in moral judgments and ethical behavior (Takahashi et al., 2014).

Moreover, cognitive abilities and reasoning styles contribute to individual differences in moral cognition (Greene et al., 2001; Moll et al., 2002; Harenski et al., 2008). Studies have shown that individuals with higher levels of cognitive flexibility and moral reasoning skills exhibit distinct neural activation patterns during moral tasks compared to those with lower levels of these abilities (Greene et al., 2001; Moll et al., 2002; Harenski et al., 2008). This suggests that cognitive abilities play a crucial role in shaping moral judgments and decision-making processes (Greene et al., 2001; Moll et al., 2002; Harenski et al., 2008).

Social context also plays a crucial role in shaping individual differences in moral cognition (Moor et al., 2018; Fiske & Rai, 2014; Tomasello et al., 2005). Socialization processes within families, peer groups, and societal institutions contribute to the development of moral values, norms, and behaviors (Moor et al., 2018). For example, parental modeling of ethical behavior and discussions about moral dilemmas can influence children's moral reasoning skills and emotional responses to moral issues (Moor et al., 2018). Moreover, exposure to diverse cultural practices and social norms can broaden individuals' perspectives and enhance their ability to navigate complex moral situations (Fiske & Rai, 2014; Tomasello et al., 2005). These social influences interact with genetic, cognitive, and personality factors to shape the multifaceted landscape of moral cognition (Moor et al., 2018; Fiske & Rai, 2014; Tomasello et al., 2005).

The implications of these findings extend beyond neuroscience and psychology, touching on areas like ethics, education, and law. Understanding the neural basis of MC could inform educational practices, potentially leading to the development of targeted interventions to nurture moral reasoning from a young age. Additionally, these insights could influence the way moral reasoning is understood in the context of legal responsibility and ethical leadership.

Conclusion

Beginning with a definition of moral competency and an overview of methods for quantifying and testing it, this paper delved into the intricate neurological landscapes that underpin moral decision-making. We explored how emotional intelligence and empathy contribute to ethical decision-making, highlighting the role of cognitive and emotional processes in moral judgment. Moving forward, neuroimaging studies, particularly those utilizing fMRI, provided insights into the neural correlates of different moral decision-making paradigms. We discussed studies illustrating the interplay between cognitive efforts and emotional responses, exemplified by seminal works such as Jung et al. (2016) and Greene et al. (2001).

Our exploration extended beyond brain region identification to consider complex neural differences contributing to individual variations in moral reasoning. In addition, our exploration included a meta-analysis using Neurosynth, which revealed consistent brain activation patterns in regions such as the Temporal-Parietal Junction (TPJ), Inferior Frontal Gyrus (IFG), and Ventromedial Prefrontal Cortex (vmPFC) during moral tasks. This convergence underscores the robustness of these neural circuits in processing moral information across diverse study samples and methodologies. Moving forward, our discussion on the neural correlates of utilitarian versus deontological judgments shed light on the neural pathways favoring one moral philosophy over another, contributing not only to neuroscience but also engaging with philosophical debates.

Moreover, delving into individual differences in moral cognition unveils a rich tapestry of factors that shape each person's unique moral judgments and decision-making processes. Genetic predispositions, developmental experiences, personality traits, cognitive abilities, reasoning styles, and social context all intertwine to sculpt the multifaceted landscape of moral competency. Understanding these individual differences not only enhances our grasp of moral cognition but also opens avenues for targeted interventions and educational practices to nurture ethical reasoning from a young age. Transitioning from this exploration of individual differences, we turn our gaze towards the implications of these findings for broader fields. The insights gained from understanding the neural basis of MC have profound implications for ethics, education, law, and ethical leadership. They inform discussions on legal responsibility, ethical decision-making frameworks, and the cultivation of ethical leadership qualities.

In conclusion, this paper provides a comprehensive overview of the chronological progression in understanding the neurological basis of moral competency. Beginning with defining moral competency and testing methods, progressing through neuroimaging studies on moral decision-making, and culminating in discussions on individual differences and philosophical implications, we've highlighted the complex yet interconnected nature of the human moral compass. This work emphasizes the ongoing need for interdisciplinary research bridging neuroscience, psychology, and philosophy to deepen our understanding of moral cognition and behavior.

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The Effect of the Acculturation Process on the Mental Health of Chinese American Youth Immigrants By Yiding Ye

Abstract

As minorities and newcomers to the United States, Chinese American youth immigrants (Newly immigrated, first generation, 13 to 25-year-olds) experience various forms of discrimination while adapting to mainstream American culture. These experiences might contribute to heightened stress for this group, leading to decreased mental well-being. This literature review confirmed this hypothesis, finding that Chinese American youth immigrants' mental health is negatively affected by experiencing various discriminatory acts and acculturative challenges. This review also identifies gaps in the current literature regarding this group and encourages further research and awareness of the mental well-being of Chinese American youth immigrants.

Keywords: Chinese Americans; acculturation stress; mental health; immigrant youth

Introduction

Asian Americans are the fastest-growing racial group in the United States in the 21st century (Budiman & Ruiz, 2021), and Chinese Americans are the largest Asian origin group, accounting for 24% of the Asian American population, or 5.4 million people (Budiman & Ruiz, 2021). First-generation immigrants also account for most Asian Americans, making up 57% of the population (Pew Research Center, 2021). While many Chinese immigrate to the United States for economic opportunities and political freedom (Cutchin, 2019), education is also an important factor for Chinese American immigrants. According to the Migration Policy Institute, China is the country of origin for the highest percentage of foreign students in US higher education (Rosenbloom & Batalova, 2023). Because most students in US higher education are under 25 (National Center for Education Statistics, 2023), the prevalence of Chinese immigrants in US higher education implies a significant amount of young adult Chinese immigrants in the United States. Furthermore, the Pew Research Center found in 2013 that around half of Asian American immigrants were under 18 years old, signifying a large amount of teenage Asian American immigrants, which in turn demonstrates a large amount of teenage Chinese Americans. These statistics demonstrate that young Chinese American immigrants, including both teenagers and young adults, make up a significant percentage of the United States population.

As an ethnic minority, these Chinese American youth (in this review, the term “youth” will include ages from 13 to 25) will likely experience various forms of racial prejudice through stereotypes, microaggressions, and discrimination. As immigrants (in this review, the term “immigrant” will be used to refer to first-generation immigrants, specifically those who were born in China and have recently immigrated), they also have to adjust to an environment vastly different from the one in which they were born by changing their behavior through the process of acculturation (Sam, 2006). Because of the many differences between the United States and

China, this modification process can be especially difficult for Chinese immigrant youth. Not only does the US speak a different language from China, but the various disparities such as governing systems (The World Factbook) and ethnic diversity (The Washington Post, 2021) can be challenging to adjust to.

When individuals encounter conflicts and difficulties while adapting to a new environment, they often experience acculturative stress (Berry, 1997). Acculturative stress is a common risk factor for mental health issues such as depression (Bae, 2020). The psychological issues that result from racial discrimination (Greene et al., 2006) and those that result from acculturative stress combined show that the acculturation process can have a significant effect on the mental health of Chinese American immigrant youth. This problem is especially important for youth, as mental health issues in adolescence are widely acknowledged to contribute to impaired physical and mental health into adulthood (Bor et al., 2014; Evans, 2017; Potrebny et al., 2017). Considering the large number of Chinese youth immigrants in the United States and the tendency for youth immigrants to feel compelled to adapt to the host culture over their heritage culture to fit into mainstream society (Renzaho et al., 2017), addressing this issue might help improve their development, social well-being, and overall health throughout their lives.

This review seeks to study the effects of the acculturation process on the mental health of Chinese American youth immigrants through a combination of experiences as Chinese Americans and acculturation-related challenges in particular. Through this combination, this review plans to provide a comprehensive overview of Chinese youth immigrants' challenges during the acculturation process and their impact on mental health, encouraging further research on this topic.

Hypothesis: The acculturation process will increase the risk of depression and anxiety while lowering self-confidence in Chinese American youth immigrants.

Methodology

The researcher largely utilized Google Scholar for scientific sources that provided support for the findings in this review. For the search process, the researcher began with the most specific keywords possible (Chinese American youth/young/adolescent/teen first-generation immigrants and the specific topic of investigation). The researcher then broadened the search keywords (i.e. Asian instead of Chinese, general immigrant instead of specifically first-generation, eliminating age restriction, eliminating US location, and expanding the scope of the topic of investigation) to expand research article options.

As there are few scientific sources specifically analyzing Chinese American youth immigrants, the researcher often expanded the scope of the search process in the above manner. This means that the majority of references in this review do not specifically analyze Chinese American youth immigrants (A gap in the literature that the researcher will expand on in the conclusion). However, all sources below do pertain to broader groups that Chinese American youth immigrants are a part of (i.e. youth immigrants, Asian Americans, immigrants of all age

groups). As part of these broader groups, it can be reasonably inferred that Chinese American youth immigrants will experience similar situations and mental health effects as these groups.

After receiving article results on Google Scholar following keyword inputs, the researcher selected articles with titles that could be relevant to the topic of investigation and looked for any relevant information in the abstracts and headings. Suppose the articles that do contain relevant information cite those pieces of information from primary sources. In that case, the researcher will browse the primary sources to verify the cited information and potentially find other relevant information. After compiling the relevant information found in the articles, the researcher categorized them into the aspects listed below that can potentially harm the mental health of Chinese American youth immigrants. Finally, in the findings below, the researcher included explanations, examples, and mental health consequences of these topics.

The Chinese American Experience

The “Model Minority” Stereotype

Asian Americans, including Chinese Americans, have commonly been viewed as able to attain high education, occupation, and economic status while having little difficulty adjusting to US culture. This has caused Asian Americans to be stereotyped as the “Model Minority,” suggesting that Asians can easily find success in American society (Sue et al., 2013) because of their perceived intelligence and work ethic (The New York Times, 2018). While this stereotype associates Asian Americans with positive traits, it can place extreme pressure on Asian Americans to conform to high expectations. Failing to meet these expectations can often create feelings of inadequacy and lead to psychological problems (Kim & Park, 2008). Furthermore, the stereotype can mask the psychological and educational needs of many Asian Americans because it is assumed that they do not need assistance (Suzuki, 2002). United States society generally expects Asian American students to be self-sufficient overachievers without mental challenges. As a result, Asian American students are not encouraged to seek mental health services, and their psychological problems are largely ignored by parents, the educational system, and society at large (Tayag, 2011).

The results can be detrimental. Studies have found that Asian American children are more anxious than Caucasian children (Tayag, 2011) and that Chinese American boys specifically have more interpersonal problems and lower social competence than the American average (Chun & Sue, 1998). Demonstrating that the “Model Minority” stereotype in particular contributes to these problems, Chun, Sue (1998), and Tang (2007) have found a significant relationship between psychological issues that are especially common among Asian American students (e.g. anxiety, depression, and social incompetence) and the “Model Minority” stereotype.

The “Perpetual Foreigner” Stereotype

Asian Americans are also often labeled by American society as “Perpetual Foreigners” who distance themselves from mainstream culture and are unassimilable (Le Espiritu, 2008). For

example, Gee et al. (2009) found that Asian Americans were the racial group that the average US adult felt the least similar to, by combining data from the General Social Surveys. This supports the “Perpetual Foreigner” stereotype, as Asian Americans are seen to be more distinct from the general United States public (Lim, 2021).

While the “Perpetual Foreigner” stereotype might not seem immediately harmful, it is considered a form of discrimination and can have drastic effects (Chan, 1991). Because foreigners are often treated with suspicion and distance, it is likely that Asian Americans, who are branded as foreigners, will be treated differently by American society (Kim et al., 2011). In fact, four studies that compared the racial discrimination experiences of white, Black, Hispanic, and Asian Americans found that the prejudice Asian Americans receive is largely because of their foreignness (Zou & Cheryan, 2017). As a result of these discriminatory experiences, the “Perpetual Foreigner” status is often accompanied by feelings of distance from society, helplessness, and frustration (Chan, 1991; Tuan, 1998). Furthermore, discriminatory experiences can undermine the opportunities available for ethnic minority children in their social interactions (Coll et al., 1996), increasing the chance of maladjustment and the development of social and mental health problems (e.g. Harrell, 2000).

The discriminatory experiences that Asian Americans can experience from the “Perpetual Foreigner” stereotype are often in the form of microaggressions. For example, Asian Americans frequently receive questions about their countries of origin and compliments on their English skills (Sue, 2010). These racial prejudices give many Asian Americans a feeling that they do not belong in their country (Sue, 2010; Sue et al., 2007). Although microaggressions can often be subtle (Sue et al., 2007), it also has clear associations with adverse mental outcomes in Asian Americans (Nadal et al., 2015; Ong et al., 2013).

Peer Discrimination

Especially for Asian American youth, preconceived notions such as the “Perpetual Foreigner” stereotype can lead to various forms of discrimination. To exemplify the prevalence of peer racial discrimination towards Asian Americans, Alvarez et al. (2006) found in a study that 98% of Asian American college students reported having encountered racial prejudice in the past year (e.g. rude/disrespectful treatment), and 99% of the students reported having seen a racist act against another Asian American in the past five years. Studies also consistently suggest that Chinese American youth specifically receive frequent discrimination, especially in the form of teasing and name-calling by their peers because of their nationality (Qin et al., 2008). Louie (2004) states that even in highly diverse cosmopolitan areas, Chinese American youth experience racial prejudices that highlight their foreignness from a young age. Because of these discriminatory experiences, Chinese American high schoolers also consistently perceive high levels of peer discrimination even when they do not frequently experience or witness it (Rosenbloom & Way, 2004).

Similar to other ethnic groups, the experience and perception of discrimination causes adverse mental effects on Chinese American youth, notably declining self-esteem and depression

(Greene et al., 2006). More importantly, research has found that peer discrimination experiences during adolescence can be particularly devastating. Green et al. (2006) and others have found that discriminatory acts by people of similar age can be more damaging to youth mental health than that by adults. Specifically, Rosenbloom and Way (2004) found that racial prejudices from other students were especially harmful to the mental state of Chinese American students.

Cultural Mistrust

Researchers have found that when people of color experience racial discrimination, they will cast more feelings of suspicion or mistrust toward the mainstream culture (Sue, 2010; Thompson & Neville, 1999). Kim et al. (2017) reason that there is enough evidence to suggest that the experience of racism can be associated with increased mistrust among Asian Americans in particular. For example, Liang et al. (2004) found in an Asian American sample that cultural mistrust is significantly related to both the number of racially discriminatory events experienced in the past year and the racism-related stress caused by the perception of racial oppression.

Although some researchers believe that cultural mistrust could be a positive and healthy adaptation for people of color who have experienced racism (e.g. Sue, 2010; Tsai & Pike, 2000), most newer research argues that mistrust is a negative condition, causing devastating social challenges such as difficulties to develop important relationships with individuals from the mainstream culture (Sue, 2010). In a sample of Asian American college students, Kim et al. (2017) found a direct correlation between the frequency of microaggression experiences and cultural mistrust, which was found to harm mental health.

The COVID-19 Pandemic

While Chinese Americans have historically and stereotypically been viewed as a public health issue, the COVID-19 Pandemic has drastically increased health-related racial prejudices against Chinese Americans (Gee et al., 2020). Because the disease was first identified in Wuhan, China, some Americans have gone on to refer to COVID-19 as the “China Virus” or the “Kung Flu” (Gee et al., 2020), most notably by former president Donald Trump, who used these derogatory terms at several speeches and rallies (Rogers et al., 2020). Trump, along with conservative experts, also accused the Chinese government of causing the outbreak of the virus through genetic experimentation in Wuhan laboratories (Boylan et al., 2021). The association of the virus with China has reinforced perceptions of Chinese Americans as “Perpetual Foreigners” and public health problems, leading to a rise in xenophobia and racism towards Chinese Americans (Borja et al., 2020).

Since the spread of the COVID-19 Pandemic to the United States, there has been increased xenophobia both on social media feeds (Tahmasbi et al., 2021) and in person in public spaces (Borja et al., 2020). The severity of these incidents is concerning. In a report from the Stop APPI Hate Coalition, Borja et al. (2020) found that hate incidents against Asian Americans regarding COVID-19 often contained violent and derogatory language towards Chinese Americans and racist depictions of the Chinese people. Furthermore, Cheah et al. (2020) found

that racial discrimination was extremely common, with close to half of the studied Chinese American population personally experiencing or witnessing anti-Chinese/Asian discrimination due to the pandemic, and with 25% of the subjects reporting witnessing racial discrimination almost every day. Finally, Cheah et al. (2020) also found that youth participants in particular perceived that Chinese Americans are seen as a public health issue in the United States.

Consistent with the studies discussed above regarding the effects of racial discrimination on Chinese Americans' mental health, Cheah et al., (2020) found that discriminatory experiences related to COVID-19 led to an increase in anxiety and depressive symptoms. Vicarious discrimination was also related to decreased mental health, specifically among youth. Finally, even if some Chinese American youth do not experience direct or even vicarious racial discrimination, referring back to previously cited studies (i.e. Greene et al., 2006), an increase in the perceived discrimination of their nationality can also be detrimental to the psychological well-being of Chinese American youth.

Acculturative Challenges

English Proficiency and Accent

Acquiring the English language is considered a foundational step in the acculturation process for immigrants to the United States, allowing them to adapt to mainstream society (Uba, 2012) and for students to master their school curriculum, helping build a successful future. However, mastering English can be difficult for immigrants who speak a different language at home (Kim et al., 2011). The Pew Research Center found in 2019 that only 44% of foreign-born Chinese Americans were proficient in English (i.e. speaking only English at home or indicating that they speak English "very well"). Although Suryantari (2018) concluded that children are generally better at learning a second language than adults, it is reasonable to assume that not all Chinese American youth are proficient in English. Furthermore, it can be difficult for students to speak like a native speaker even when they have acquired fluency in English, with their accents indicating their foreign status (Kim et al., 2011). This is confirmed by Qin, Way, and Mukherjee (2008), who found that Chinese American youth who spoke in a non-standard American accent were more likely to be labeled as foreigners.

According to Coll et al. (1996) and the sources mentioned above regarding the "Perpetual Foreigner" stereotype, indications of foreignness or immigrant status can sustain the "Perpetual Foreigner" stereotype, which in turn can increase the likelihood of youth experiencing discrimination. This is supported by Qin et al., (2008), who found that a lack of English skills and having a non-standard American accent caused minority youth to be discriminated against by their peers at school. Additionally, Cargile (1997) found that people were rated as less attractive when they gave speeches with a Chinese accent compared to an American accent. Finally, Kim et al., (2011) concluded that English proficiency is related to the psychological well-being of Chinese American youth through "the indirect effects of speaking English with an accent, being stereotyped as a foreigner, and perceiving discriminatory experiences."

Social Exclusion

According to the “social misfit” theory (Wright et al., 1986), when individuals differ from the majority in one or several characteristics, they are more likely to be rejected or discriminated against by the dominant social group. Just like the ethnic minority status of being Chinese American, an immigrant background is also a characteristic that leads to discrimination (Jackson et al., 2006; Vervoot et al., 2010). For example, in a study conducted in Swedish schools, Plenty and Jonsson (2017) found that first-generation non-European immigrant status placed youth at greater risk for isolation and rejection at their schools. They also found that first-generation immigrants were more likely to be victimized, isolated, and bullied in classrooms where they comprised the minority compared to second-generation immigrants, demonstrating immigrant status specifically as a contributing factor to peer discrimination.

As peer acceptance is particularly important among youth and can promote a sense of self-worth and identity (Berndt 1999; LaFontana and Cillessen 2010), social exclusion during this period can be particularly damaging to youth’s school adjustment and mental health (McCormick et al. 2011; Östberg and Modin 2008; Wolke et al. 2013). This issue is even more important for immigrant youth. Because they have to adjust simultaneously to their school environment and the mainstream culture, engagement with peers can help further proficiency in the mainstream culture and language (Berry et al. 2006).

Generational Acculturative Dissonance

As immigrant youth are more exposed to host culture and values than their parents because of their involvement in school and social media, they have a greater desire to adapt to the host culture for the acceptance of their peers and have more opportunities to do so (Okagaki & Bojczyk, 2002). As a result, Costigan and Dokis (2006) found that Chinese Canadian children favored English in their speech and media use and aligned with values regarding independence more than their parents. Reaching a similar result with the children of immigrants, Rumbaut (2005) explains that they have a higher chance of adopting aspects of American culture while their parents are more likely to remain grounded in their cultural heritage. With these differences in their adaptations to the host culture, immigrant parents and children experience acculturation dissonance, a discrepancy between their cultural ideologies (Portes & Rumbaut, 2001, 2024).

According to Lee et al. (2000), acculturative dissonance can lead to conflicts between Asian American youth and parents over culturally important topics such as “respect for elders, academic achievement, and sacrificing personal goals for the sake of the family.” This stems from fundamental ideological differences between Eastern and Western cultures, as while the United States promotes individualism and the accomplishment of personal goals, Chinese beliefs are more collectivistic, emphasizing obedience and conformity (Zha et al., 2006). This can have detrimental effects on immigrant families. Juang et al. (2012) found that acculturation-based conflicts can cause poor parenting and distant parent-child relationships, which can lead to lower youth adjustment in the acculturation process. Similarly, many studies have found links between acculturation-based conflicts/acculturative dissonance and various psychological issues in Asian

youth such as depression, anxiety, and low self-esteem (Baolian Qin, 2006; Costigan & Dokis, 2006; Juang et al., 2007; Lee et al., 2000; Lim et al., 2008).

Bilingualism and heritage language loss

Bilingualism is common among immigrants, even those born in the United States. Alba (2004) found that 61% of second-generation Asian Americans spoke their heritage language. Considering first-generation immigrant's further exposure to their heritage cultures, this number is likely higher among Chinese American youth immigrants. Because of their proficiency in both the host and heritage languages, immigrant children often have to take on the role of interpreters or translators for their parents, who do not adapt to aspects of the host culture, such as language, as quickly (Okagaki & Bojczyk, 2002). For example, Lim (2021) found that Asian American immigrants often found themselves ordering for their parents at restaurants because the employees dismissed the parents for their lack of English proficiency. While some research has found that bilingualism can further connections between immigrant youth and their parents (Zhou & Bankston, 1998), translation work can often become complicated when youth are asked to relay information about topics they do not typically engage in, such as financial, legal, and controversial issues (Orellana, 2009). Given the more mature nature of these topics, most youth will likely find it difficult to navigate them and feel stressed. Therefore, it is reasonable to assume that translating for parents, while providing some benefits, can harm the mental health of Chinese American youth immigrants.

The loss of a heritage language can also cause emotional harm to Chinese American immigrant youth. According to Hinton (2009), immigrant youth sometimes "reject" their heritage language, often due to embarrassment from peer discrimination of their accent or heritage language use. With this rejection, immigrant youth can gradually lose their proficiency with their heritage language. Hinton explains that this loss of proficiency can cause regret among these immigrant youth as they grow older and realize their desire to be fluent in their heritage languages. It can also lead to communication difficulties and rejection from older-generation family and community members. Utilizing the above findings regarding the effects of generational dissonance, heritage language loss is likely also to decrease psychological well-being for Chinese American youth immigrants.

Conclusion

This literature review concluded that the various challenges of the acculturation process, together with the racial discrimination from stereotypes and the COVID-19 pandemic, can greatly affect the psychological well-being of Chinese American youth immigrants through decreases in self-esteem and increases the risks of anxiety and depression. First, because of their ethnic minority status, Chinese American youth frequently experience various forms of racial stereotyping, microaggressions, and discrimination from those around them, decreasing their trust in American society. These racial prejudices also worsened in recent years due to the COVID-19 pandemic. Furthermore, because of their immigrant status and accent or lack of

English fluency, these Chinese American youth are often labeled as foreigners, receiving discrimination and exclusion. Finally, differing rates of acculturation between adult and youth immigrants and youth immigrants' complex relationships with their heritage languages can create domestic challenges. All of the challenges above can lower Chinese American youth immigrants' psychological well-being, often resulting in lower self-esteem and a higher likelihood of anxiety and depression. These findings support the researcher's hypothesis, which states that the acculturation process will lower self-confidence and increase the risk of depression and anxiety for Chinese American youth immigrants.

Gaps in the Current Literature

As mentioned in the methodology, there are few sources that directly investigate the acculturation process of Chinese American youth immigrants. Although many experiences of assimilating to a new culture or life in the United States have been documented through broader groups, there are a few specific gaps in the literature that if investigated, could provide more information on this topic and provide a more comprehensive view on the experiences on Chinese American youth immigrants:

- *The effect of negative views towards the Chinese government on Chinese American's sense of belonging.* Due to the rise of hostilities between the United States and China in recent years, as evidenced by developments like the trade war during Donald Trump's presidency (Boylan et al., 2021), the Chinese government has been increasingly antagonized by the US government and the public. While the majority of hostilities are directed at the Chinese government, these hostilities could increase discriminatory acts towards Chinese Americans and increase Chinese Americans' perceptions of discrimination, both of which have been shown to have negative mental health consequences.
- *The effect of differences in the United States and Chinese educational systems on the acculturation of Chinese American immigrant students.* There are drastic differences between the American and Chinese educational systems, with differing emphasis on skills like creativity and standardized testing as well as approaches to processes like college admissions. This can represent a huge change for Chinese immigrant students, who might find it difficult to adjust to this new educational style while maintaining grades and relationships with peers, which can lead to feelings of inadequacy for life in the United States. As a result, these differences in the educational system could cause stress for Chinese immigrant students, leading to decreased psychological well-being.
- *The ability for Chinese American immigrant youth to develop long-term, meaningful connections with peers.* While most current studies have focused on assimilating to American culture and peer acceptance of immigrants, an important factor that could help measure the long-term acculturation of Chinese American youth immigrants is the ability to develop long-lasting, meaningful relationships with their peers. This is because Chinese American youth immigrants can take time to fully assimilate to the various

aspects of American culture, making it difficult to develop close friendships quickly because of a lack of connections between them and their peers. If it is difficult for Chinese American youth immigrants to develop these types of relationships, that could further impact their mental well-being.

- *The rate of popular culture acquisition by Chinese American immigrant youth and its effects on peer relationships.* Popular culture can evolve incredibly quickly among today's youth. Because of this, it can be difficult for Chinese American youth immigrants to grasp the subtle, changing elements of popular culture as they also have to adapt to other aspects of the overall American culture. This difficulty in the acquisition of popular culture could increase the gaps between immigrant and native students due to a lack of mutual connections, potentially leading to isolation and peer exclusion.

Closing Remarks

Overall, this literature review highlights several aspects of Chinese American youth immigrants' struggles as they assimilate into United States culture. These challenges reveal Chinese American youth immigrants as a potentially vulnerable group as their psychological well-being, being negatively affected by a combination of these challenges, is likely significantly lower than the majority of Americans. This is an important issue as Chinese American youth constitute a considerable portion of the American population and recognition of the importance of their mental health could benefit related groups as well. The researcher hopes that more investigations will be done on this topic in the future and that this review can help Chinese American youth immigrants, their families, peers, educators, and American society at large identify the various challenges that this group faces during the acculturation process to spread awareness about the mental tolls of the situation and encourage the group to seek help when needed.

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Parasocial Relationships and Political Interest during Adolescence By Helena Jiang

Abstract

A parasocial relationship, or PSR, can be categorized under the broader range of parasocial experiences (PSEs), illusory encounters between an individual and their perceived connections with various media figures or online characters. These relationships are typically non-reciprocal, but can be just as socially and emotionally valuable to the viewer as an interpersonal relationship would be, to the extent where parasocial breakups may be as emotionally distressing as interpersonal ones. Parasocial relationships are important to understand as they are a phenomenon that explores how mass media affects the general population. This phenomenon becomes especially critical as social media and mass media continue to grow, play a bigger role in our day-to-day lives. The review examines existing literature on parasocial relationships, with thematic elements to explore specific research done on politically active social media accounts, and how they can affect adolescent development—particularly their political interest and/or engagement as they mature. PSRs may play a role in a person’s political activity as politicians begin turning towards social media as a new way to draw support from the population. This research is relevant for social psychology, specifically the implications of parasocial relationships during adolescence, education and educators in their efforts to increase political interest in the classroom, and politicians as contemporary campaigning methods continue to change. Implications for future research in these realms will be discussed.

Introduction

In 1956, Horton and Wohl discovered a phenomenon between spectators and performers in mass media (Horton & Wohl 215). This discovery was termed “parasocial relationships.” The prefix “para-” refers to an abnormal phenomenon. The root word, “social,” is defined as “tending to form cooperative and interdependent relationships with others.” Together, the word “parasocial” describes an “abnormal (irregular) interdependent relationship.” Many notable researchers have done studies to further understand the phenomenon (Cohen; Kurtin; Lather & Moyer-Guse). Consequently, the nature of parasocial relationships has changed throughout time as increasingly progressive forms of media and technology began to dominate the world. It is now more accurately defined as an intimate, one-sided interpersonal relationship that could be either platonic or romantic between a viewer and a media figure, which ranges broadly from internet personalities, celebrities and actors to fictional characters and personas.

Because children have increasingly unlimited access to the internet at earlier ages (Laricchia), it is important to study social media and social media influencers; specifically how media facilitates parasocial relationships (PSRs) and how these PSRs may affect adolescents’ transition to adulthood. Early parasocial interactions or relationships may influence children through adulthood, especially during the critical period of adolescence when children begin to gain autonomy from their parents and turn towards the social sphere for support (Giles & Maltby

813). Furthermore, political participation has been declining as a result of decreased political engagement and interest starting in adolescence (Eckstein et al. 485), and interaction with the democratic process has been below its peak (Levy & Akiva 1039). Research suggests that parasocial relationships and interactions may be key to combating this decrease, through their predictive value (Cohen & Holbert 501), unconscious influence (Paraviti et al. 388), perceived intimacy from interpersonal tones on social media (Dunn & Nisbett 27), and when combined with source similarity and trustworthiness (Harff 97). This literature review provides an in-depth investigation into modern parasocial relationships, highlighting its importance in political engagement during adolescence today.

The Importance of Parasocial Relationships

Parasocial relationships are non-reciprocal, socio-emotional connections between a viewer and a character – who can be fictional or non-fictional – formed similar to the development of interpersonal relationships (Rubin & McHugh 279). Research has suggested that the human brain processes mediated experiences (e.g., experiences that were planned out, such as in a TV show with a script) in a way similar to directly lived experiences (Kurtin 233). Because of this, individuals tend to respond to parasocial interaction like they do to interpersonal interaction.

It is important to differentiate between parasocial interactions (PSIs) and parasocial relationships (PSRs). The former often refers to one specific instance of interaction or exposure, such as choosing to watch a video or put on a show (Rosengren & Windahl 347). The latter is defined by an ongoing and repeated viewer-performer exchange, such as subscribing to a channel or watching every new episode of a TV program (Horton & Wohl 215).

A popular theory that exists regarding interpersonal relationship development is the “uncertainty reduction theory,” (Berger & Calabrese 99) where two people interact primarily to reduce uncertainty between them. The theory relies on communication, liking, and intimacy. Like typical interpersonal relationships, these three factors are also critical to parasocial relationships. Communication occurs via media exposure, where a person watches a character perform; if they enjoy the character, they will move onto liking, or attraction. Intimacy is strengthened through repeated exposure to the character, or parasocial interaction. This is the primary theory for parasocial relationship formation (Rubin & McHugh 279). However, Rubin and McHugh disagreed with the main hypothesis that increased exposure led to increased attraction; they found that in reality, social attraction and reinforcement theory- where people tend to seek out information that supports their pre-existing beliefs, or reinforces their liking of certain things- were better indicators of parasocial attraction formation and strength. If a viewer found a character socially attractive, and could envision them as a friend or partner, there was a higher engagement in parasocial interaction (Rubin & McHugh 279). From increased PSIs, a PSR would gradually form. Lastly, they validated the PSI scale as it measures a viewer’s attraction towards a character and how much they value their connection to the character. The PSI scale has been utilized and reformed in PSI and PSR research (Auter & Palmgreen 79),

primarily to identify the strength of certain interactions and how it plays into the formation or strengthening of parasocial relationships.

Because PSRs often complement offline bonds, or everyday social interactions, Hoffner and Bond explored the effects of parasocial relationships through media and found that the relationships could be beneficial for a person's emotional and even physical health. Due to healthy advertising by influential media figures, the viewer may be influenced to follow healthier standards of living for themselves. Additionally, in terms of mental health, PSRs have the potential to facilitate coping processes, as well as bring eudaimonic well-being through inspiring self-development, self-realization, and growth (Hoffner & Bond 101306).

However, PSRs also have the potential to induce emotional distress, during something known as a parasocial breakup, where a parasocial relationship terminates due to either a loss of interest, the source ending and characters disappearing (PSB; Cohen 187). Examples include television shows ending, or characters no longer being played on stage. Through his experiment, Cohen suggested the existence of a link between PSRs and attachment styles- emotional attachments formed with others, of which there are primarily four: secure, avoidant, anxious, and disorganized. Anxious attachment (characterized by low self-esteem and fear of abandonment) displayed the greatest PSR intensity, and therefore the greatest distress when facing the possibility of a parasocial breakup. Interestingly, secure (confident and healthily interdependent) and avoidant (who often have trouble with social relationships) attachment styles both displayed low levels of parasocial interaction and subsequently lower signs of distress when facing a parasocial breakup. Cohen concluded that PSRs depend on the same psychological processes as real-life intimate relationships, and provided an avenue for further study through looking at the emotional effects of PSRs and PSBs in relation to a viewer's personality. An important theoretical implication this research suggests is that PSRs should be seen as an extension of social relationships, not a replacement for them, as avoidant personalities did not show great distress when faced with PSB as Cohen hypothesized.

Similarly, Lather and Moyer-Guse looked at the implications of parasocial breakups using the Hollywood writer's strike from 2007 to 2008, when many popular television shows were temporarily taken off-air. Their first prediction was people who had stronger PSRs would experience more distress when facing a temporary PSB. Their findings supported this hypothesis; parasocial relationship strength was the greatest predictor of parasocial breakup distress. Specifically, people who viewed TV for companionship developed stronger PSRs which, as previously determined, predicted greater distress during PSB, temporary or otherwise.

Lather and Moyer-Guse then examined what activities television viewers would turn to due to the interruptions and to what extent they would engage in them. They found that after, or in this case during, a parasocial breakup, individuals were more likely to increase other media engagement (such as watching TV reruns, browsing the internet, and watching movies) than turn to non-media activities. This suggests that television viewing displaces interpersonal interaction; rather, it is a different type of relationship that people have integrated into their day-to-day lives, and when disrupted is more likely to be replaced by other media-related relationships.

Television viewing, or how much an individual likes watching television was also a significant predictor of parasocial breakup distress (Lather & Moyer-Guse 196). Greater affinity for the activity led to greater distress when it was interrupted. Interestingly, those who watched the most hours of TV did not experience the same amount of distress, perhaps suggesting that enjoying television and fondness for television are separate. Additionally, those who viewed television for instrumental reasons, which is for an aim or goal, experienced greater distress compared to those who saw television as a leisure activity (ritualistic viewers). This was because ritualistic viewers still had other types of content available to them, while instrumental viewers had trouble dealing with their specific show going off-air (Lather & Moyer-Guse 196).

To conclude, parasocial breakups do not need to be permanent to cause distress. Watching television for instrumental or companionship reasons predicts greater emotional turmoil due to parasocial breakups. Lather and Moyer-Guse observed a significant amount of discomfort will be produced if the stability of a parasocial relationship is threatened. This further suggests similarities between PSRs and interpersonal relationships, as well as the stages of development and dissolution for both.

Parasocial Relationships and Social Media

Media has evolved to encapsulate much of our lives today. From Horton and Wohl's first discovery, which drew on the relationship between TV actors and viewers through a screen, there has been a plethora of new platforms to evaluate PSRs on. Social media is a relatively new addition to parasocial relationship research, and is being heavily studied due to its easy accessibility and increased intimacy. Unlike television in previous decades, social media apps such as Youtube, Twitter, Facebook, Instagram and Twitch have made connecting with influencers and celebrities easier than ever; hence why parasocial relationships are more important to understand now.

Kurtin delved into the nuances of PSR formation on Youtube, a social media platform where anyone can become a content creator through uploading videos and gaining a fanbase. They found that PSRs were generally formed with three steps: communication, liking, and intimacy. These three steps correlated to attraction, parasocial interaction, and relational importance, and all were crucial to forming and maintaining a PSR. Furthermore, a likeable personality seemed to form more PSRs with the viewers rather than physical attraction and frequent exposure, although the latter promotes parasocial interactions.

On Youtube, PSRs are promoted intentionally by creators. When looking at creators with large fanbases, their content often mimics direct interaction with a viewer – e.g., thanking viewers for continued support, talking to them as if they are in the room or right across from the creator, making eye contact with the camera– further facilitating the formation of PSRs. This is empirically supported by Chen's research on content creator's construction and presentation strategies of the digital self on YouTube. Chen and their team examined three types of data: Youtube videos, face-to-face interviews with the Youtuber, and electronic exchanges with the audience. They first determined how creators self-construct and self-present by looking at

Youtube videos. Then, through the interviews, the how and why of self-presentation strategies were revealed. Finally, looking at electronic exchanges filled the gaps in data analysis. To accomplish data collection, they created a code sheet to analyze Youtube videos for significant signs of the digital self. The interviews then served as useful supplements to the researchers, to modify their view on the Youtuber's digital self.

One way the construction occurs is through impression management (Goffman 631), where a person projects their desired impression onto others through communication. It is maintained through performing behaviors that align with who they want to be seen as, regardless of whether their true character is the same. This presentation is also contextual, as the way one appears from setting to setting changes often. Jones and Pittman created a theoretical model based on Goffman's work that is still popular today. Digital selves on Youtube or other social media platforms are enhanced through lived and mediated experiences. Lived experiences are first-hand accounts from personal life, while mediated experiences are gained from second-hand or outside sources. Often, creators will draw inspiration from their own consumption of media.

Additionally, gender is a crucial component of someone's digital self. Because Chen's research focused on Taiwanese culture, gender expression was especially important. Symbolic representations of gender, which vary from culture to culture, are often used by creators to craft the ideal gender role. YouTube is seen as an unlimited space for freedom of self expression, where people can create identities completely different from their real ones. However, the line between digital personas and real life is often blurred; cultural values still heavily affect how content creators approach the construction of their digital selves.

Chen discovered four main strategies for digital presentation, namely (1) basking, (2) mystification, (3) self-promotion, and (4) gender-switching. Basking is when a creator capitalizes on a celebrity's fame, by associating their image with famous figures, copying an idol's works or drawing heavy inspiration from them. This creates favorable images of the smaller creator, especially if the celebrity they are imitating is well-liked. It is somewhat like taking a bit of their glory to enhance the creator's own profile. The second strategy, mystification, is a strategy where creators intentionally mask their physical attributes so that viewers can focus on their talents. It is used for creating likeable personas, by hiding undesirable traits and exemplifying desirable ones. Viewers are drawn to an atmosphere that keeps them guessing, and many examples of this have appeared over the years (deep-voiced creator "Corpse Husband," popular Minecraft creator "Dream"). Self-promotion is exactly what is implied; the promotion of special abilities the creator has. Acts are still enhanced by repeated rehearsal and special gestures to ensure the "right" appearance, in line with the identity they want to exude.

Youtube is filled with masks of identity; it can serve as the ideal place for fantastical personas. This is exemplified by creators who participate in the "gender-switching strategy." While seemingly harmless and even sometimes playful, it can have serious negative consequences depending on cultural norms. For example, a few Taiwanese content creators from Chen's study experienced negative backlash through participating in gender-switching. One of

them, who as a man had the voice of a famous female singer, received a large amount of hate after he revealed his face and real identity.

PSRs and PSIs are determined by “click-rates,” or how much viewers interact with the creator’s videos. The positive feedback gives the creator the confidence to produce more content. This type of success can invoke self-actualization. To a creator, parasocial relationships are an invaluable source of support for online performances (Chen 232).

Kim and Song studied how a celebrity’s personal and professional self-disclosure helps foster fans’ parasocial relationships. They discussed the concept of social presence, or psychological involvement with others in a mediated environment. However, according to recent research, the fans’ interactions between themselves should be referred to as “social space,” which is a form of peaceful group cohesion while social presence is the specific relationship fostered between the fan and the creator (Kreijns et al. 139).

Twitter is a different environment because of the ability to “retweet,” or post a person’s tweet (a piece of text limited to 280 characters maximum) onto your own page. Those highly involved on social media platforms, particularly Twitter, develop stronger PSRs the more a celebrity shares about their life (Kim & Song 570). A celebrity who often shares their experiences with their fans tend to have a stronger fanbase, as their fans feel a strong social presence similar to how talking to a friend (interpersonally) would feel. Overall, Kim and Song looked at how celebrities enhanced parasocial interactions through self-disclosure on Twitter. Their results are broadly applicable, as the same could be argued for other social media apps as well, such as Instagram.

Garimella et al. conducted further research into parasocial interaction on Twitter, specifically parasocial breakups. These manifest on Twitter through the act of unfollowing a celebrity. While Lather and Moyer-Guse focused on the effects of an unwanted parasocial breakup, Garimella et al. looked at the fan’s personal decision, with control over breaking up. They observed three different types of fans: (1) involved, who regularly interact with the celebrity, commenting on their posts expressing immense adoration; (2) casual, who occasionally interact with celebrity posts (defined as “at least once in the previous year” in this study); (3) random, who do not need to display anything besides simply following the celebrity. The three types were predicted to display a varying intensity of emotion regarding the PSB. The predictions were interpreted using the idea of cost/benefit. The more involved a fan is with a celebrity, the stronger the parasocial relationship. This leads to a strong emotional attachment to and investment in the celebrity, and when their emotions are neither rewarded nor reciprocated, the fan is more likely to end the PSR. Involved fans, more obsessed with the creator, would therefore be more likely to “break up,” unlike fans from the random group.

When analyzing demographics, the researchers found that young, female fans are a majority of the involved fan groups. Garimella et al. made an imposing argument as to the implication of their research. As more celebrities, influencers and now even politicians continue to use social media platforms to cultivate their following, it is very important to study how PSIs, PSRs, and PSBs are facilitated online.

Parasocial Relationships and Adolescence

As the media has evolved over time, more ways to interact with a celebrity and peer into their personal life have appeared. In the past, parasocial interaction was limited to seeing characters on the TV, through their performance on shows or interviews. With the introduction of social media such as Twitter and Instagram, interacting with a celebrity is easier and immediate. Celebrities have also taken advantage of this development by garnering a mass social media following. Because it is easier to make posts on new social media platforms, PSI have become more frequent. There are also new ways to interact parasocially, such as liking and commenting on a post or privately messaging the influencer on the platform.

With younger generations being introduced to this new technology at increasingly younger ages, their social media engagement is at levels beyond media engagement in the past. Adolescents in particular spend much of their time online, interacting with favorite media figures, influencers and celebrities (Anderson & Jiang). Following this trend, it is important to analyze parasocial relationships and interactions in adolescents, noting the differences between the past and now, as well as how the future may be affected by the upwards trend in technology and social media platform usage.

Bond (656) conducted a study with middle and high schoolers from southern California to assess their parasocial relationships on social media. He looked at frequency, realism, and response to parasocial interactions to draw conclusions about factors affecting the strength of PSRs in adolescents. Three hypotheses were given in his study. The first was that a positive relationship should exist between PSR strength and exposure to favorite media personae. As an adolescent's exposure to media personae and celebrities increase, the strength of their PSR should also increase. For his second hypothesis, Bond drew on a study from Giles, suggesting realism as an important trait in parasocial relationships. Thus, those who engage in PSRs with non-fictional characters will have stronger relationships than those who engage in PSRs with fictional characters. Lastly, his third stated that adolescents who have received interaction from their favorite influencer online - two-sided parasocial interaction - will display stronger PSRs than those who only interact one-sidedly.

Bond collected information about parasocial interaction on four of the most popular platforms for adolescents at that time: Instagram, Twitter, Facebook and Snapchat. He found that only Twitter contributed significantly to PSR strength. There was no significant difference between the strength of a PSR with a non-fictional character and a fictional one. Although there was little two-sided interaction, the data collected was enough to support Bond's third hypothesis as the few adolescents who had received responses from their favorite celebrities, through a repost or reply, displayed stronger PSRs.

To explain why only Twitter contributed significantly to PSR strength, Bond cited studies indicating that the platform's unique features made interactions more authentic. For example, the prevention of editing after posting on Twitter could be perceived as an indication of legitimacy by the audience. Additionally, the frequency from the ease of posting on Twitter could also account for stronger PSRs. Because interactions are frequent, through celebrities posting more

often on Twitter than other platforms, adolescents can receive constant glimpses into the personal life of an influencer. Realism was not a significant factor in determining PSR strength, but this may be a result of Twitter giving fictional characters a new form of expression. Although adolescents understand that accounts imitating fictional characters are not realistic, it seems that parasocial relationships may be further developed this way. Future research could look at how imitation accounts can strengthen parasocial interactions in fans of fictional characters.

Bond (659) did note a few weaknesses in his study, including the low number of males and adolescents reporting two-sided interactions with their favorite media personae, and the acknowledgement of “ghost-tweeting” (where an assistant posts for the celebrity rather than the celebrity posting themselves). In the future, it may be helpful to consider how both these areas may affect the strength of PSRs in adolescents. Future research can also focus on how PSRs on other social media platforms are affected, despite Twitter being the primary enforcer of parasocial relationship strength.

Eyal et al. also provided an important implication: adolescents may be influenced by celebrity postings and appearance in media while developing self-identity. They looked at the contents of celebrities’ social media posts to determine how they are enhancing PSI with adolescents, and how that leads to increasing adolescents’ value on the idea of fame, or fame-valuation. They observed two things: breadth, which refers to how many topics are covered by the influencer, and depth, which refers to how personal the influencer gets in their posts. Regarding breadth, the most common type of posting was about celebrities’ professional lives, followed by self-promotion and then personal. The other types, such as addressing health, friendship, or political/social topics were rarely discussed in celebrity posts.

While Eyal et al.’s research focused primarily on how celebrities portrayed themselves on social media platforms and the content of their posts, it is crucial to understand this content and the intention behind posts. Perhaps in grasping their influence on adolescents, celebrities tend to stay away from more provocative subjects and posts. Surprisingly, few of them posted about political and social activism. The researchers speculated the lack of attention paid towards these subjects is due to the celebrities’ belief that their discussion would not go very far outside of the post. All the celebrities chosen for this study had a wide adolescent following, and although not much can be drawn about that audience from here, the data does give evidence for celebrities’ awareness of their younger following. Despite this sample group not catering much towards them, the fact that this awareness exists could be explored in further research to understand how the adolescents themselves are affected and how influencers can alter their posts for a younger audience.

Following the effects of influencer posts, Giles and Maltby (813) looked how adolescents incorporate the impact of such content into their own development. The experiment studies the relationship between two concepts: secondary attachments and adolescent autonomy. “Secondary attachments” (Adams-Price & Greene 187) are attachments to distant figures. Media figures begin to have a stronger influence on adolescents’ development as they struggle with forming their separate identities (Erikson). These influencers offer a glimpse into the many different

selves that a teenager may find intriguing and want to incorporate into their own self-identity. Giles and Maltby's main hypotheses stated that as adolescents grew more autonomous, their interest in media figures and celebrities would also grow, possibly indicating a shift from idolizing their parents to idolizing influencers. Additionally, the researchers also looked at adolescent attachment and two functions of celebrity influencers - entertainment and personal (Maltby et al. 1157). They predicted seeing celebrities more as entertainment would indicate positive attachment to peers, while having a sense of personal relation to a celebrity would indicate negative attachment to peers, or any surrounding loved ones.

To analyze the relationship between autonomy and attachment to parents, Giles and Maltby (817) used Steinberg and Silverberg's (841) EAS, emotional autonomy scale which asked adolescents their perception of independence from their parents. Celebrity interest was measured using McCutcheon et al.'s (67) CAS, celebrity attitude scale. Attachment, to various objects such as peers and romantic partners, was measured using AORI, or the Attachment and Object Relations Inventory developed by Buelow et al. (604).

The results suggested that the first hypothesis was true; as adolescents began to idolize their parents less, media figures gradually filled gaps left by the shift. Additionally, Giles and Maltby (813) found a positive correlation between celebrity interest and peer attachment, indicating a mutual effect between them. For the two factors, the results also fell in line with the hypotheses. The first factor, celebrities as social or entertainment functions, was predicted by high attachment to peers but low attachment to parents and low levels of closeness. The second factor, forming relationships with celebrities in more personal ways, was not significantly related to either peer or parental attachment. Giles and Maltby hypothesize that developing intense, personal relationships (similar to PSRs) with influencers may happen during times of stress or in those who experience negative peer interactions. This would correspond with theories that explain PSRs as an alternative form of social interaction for people experiencing loneliness and isolation.

Although Giles and Maltby's study was effective in proving media figures becoming more influential in adolescents' lives, the research cannot conclusively suggest that influencers are serving as role models; to make this suggestion, further research should be conducted into the type of perceived attachment between the adolescent and influencers.

As previously suggested, individuals' attachment style is significant to the formation, maintenance and resolution of parasocial relationships (Cohen 516). Theran et al. incorporated Bowlby's three types of attachment - secure, dismissing, preoccupied - into their hypotheses. These three attachment types correspond to those discussed previously: secure, avoidant, and anxious. Those with anxious or preoccupied attachment styles may often believe they are unworthy of love due to inherent, personal flaws. Furthermore, PSRs in adolescents may also hold significance, especially because of developing autonomy during this period of life (Giles & Maltby 813). Theran et al. (270) decided to focus on adolescent girls in particular due to research suggesting their higher involvement in PSRs (Cohen 516) and their tendency to imitate the lifestyle and habits of the celebrities that are the target of their idolization (Giles & Maltby 813).

The researchers' hypothesis predicted that a majority of the girls would report having PSRs and that a preoccupied attachment style could indicate more intense parasocial interaction.

Theran et. al's results indicated that while most reported experiencing relationships with celebrity figures, the attraction was more distanced and less involved. They saw their idols as just that - idols, rather than accessible partners. The same results can be drawn regarding previous work indicating attachment styles' effects on PSR intensity: preoccupied attachment could predict stronger PSIs. In a way, Theran et al.'s study added to prior research suggesting that inner relationship models could be brought out by PSRs, despite parasocial relationships being generally unable to alter the models and foster healthy, secure attachment, due to reciprocation being extremely unlikely.

Political Interest and Engagement in Adolescence

According to Anderson et al., youth voter turnout has declined over the years. Levy and Akiva (1039) examined how political engagement is fostered in adolescence and found that voter turnout in the United States had been below its peak compared to the past (U.S. Elections Project). This low participation has had negative consequences, such as electing representatives who do not represent the people or are inattentive to their needs. Functioning members of society need to interact with politics to preserve and enhance the democratic processes. Adolescents frequently report low participation in politics, despite understanding that being involved in politics is an indicator of a "good citizen," (Eckstein et al. 485). To mitigate the negative effects and increase political engagement, interest in politics must be fostered from a young age (Kahne & Bowyer). Adolescence is a critical stage in life where children are beginning to form a sense of self-identity (Erikson). Many may choose to begin immersing themselves in the political world. Researchers believe this is the key to increasing voter turnout in democratic nations (Eckstein et al.; Kahne & Bowyer; Levy and Akiva).

Levy and Akiva (1039) begin by introducing two types of political thought: political interest and efficacy. Political interest is defined as how important individuals view politics to be in their life and how willing they are to participate (Lupia & Philpot 1122), while political efficacy is the extent to which people believe their vote can influence the government (Beaumont 525). They also differentiate between IPE, internal political efficacy, and EPE, external political efficacy. The former is a person's grasp on their competence within politics, while the latter is how much a person believes a government will respond to actions stemming from that competence (Levy 1039).

Levy and Akiva's paper introduces two main hypotheses: (1) political efficacy and interest positively impacts adolescents' willingness to engage in politics in the future, and (2) males, whites, older students, and those with higher SES backgrounds would have higher political engagement, based on prior research.

The findings suggest that education can help support political interest and efficacy, motivating students to interact with democracy (Levy and Akiva 1039). Political interest may be stronger than political efficacies in predicting future political involvement; education should

focus on ways to increase political interest. Additionally, IPE and political interest may be mutually beneficial, as the data indicates that being confident in both personal political skills and having an interest in politics leads to higher engagement in the future.

Research also suggested that as students approached voting age, they became increasingly interested in the political sphere. Thus, it is important to foster political interest in late adolescent development to encourage teenagers' heightened interest in the democratic process. Ideas and ways this can be done have been explored by various organizations, but introducing the concept of civics from a young age, inclusion of youth voices in law and policy, and avoiding political misinformation are the general trends between ideas to raise political participation (Community of Democracies, 2021). Being part of a minority group may also contribute to decreased interest in politics, due to subjugation or lack of EPE. Future research should center around a broad range of demographics to better predict how the adolescent population can engage in the political sphere.

Meanwhile, Eckstein et al. wanted to better understand how adolescents develop their roles as citizens. They look at this process in two ways: firstly, it is dependent on adolescents' educational level or track; secondly, how strongly these factors contribute to the stability of a teenager's involvement in politics in later life. Since the study was conducted in Germany, the researchers studied the differences between two different tracks: college-bound and lower school track, which targets practicality. Those who target the college-bound track reported higher political interest and saw political engagement in a more positive light (Gaiser & De Rijke 541). Besides political selection, which is a student's socio-economic and familial background, political socialization also plays a large role in explaining differences between the two tracks. Political socialization refers to the opportunities for engaging with politics surrounding an adolescent. This and how often and how supported factors encouraging political interest are pushed onto the students pursuing either track primarily explains the difference between the two tracks' levels of political interest.

Eckstein et al.'s study aimed to explore the development of adolescents' political attitudes, political interest, and willingness to engage in politics at a later age. They predict that differences between school tracks will only persist and even widen over time as each group continues experiencing their separate political socialization. Lastly, Eckstein et al. hypothesize that political behaviors become more stable. The results of the study were surprising. Firstly, they found that adolescents were most susceptible to attempts to raise political interest during middle adolescence, so efforts to increase engagement should be considered. School track differences (college-bound vs practical) in political interest did not emerge until later adolescence, around the 9th grade for those on the higher track. This may likely be due to different socialization experiences, such as extracurriculars, curriculum difficulty differences and peer interactions. However, selection or socio-economic background should also not be ruled out, as previous research has shown that those from higher socio-economic backgrounds tend to be more politically involved, perhaps because of their childhood environment or simply more opportunities to engage in politics. Thus, lower-track students should receive support to boost

their political interest and awareness, through education or other means. This is especially important right around mid-adolescence, where the difference between the two tracks becomes more apparent.

Regarding the stability of involvement in politics, Eckstein et al.'s data are weak in suggesting adolescents' political orientations become more consolidated, and thus, their willingness to participate in politics also increases. Despite this, teenagers reported higher stability in their willingness to participate than their attitudes toward political engagement. While this study has its limitations, such as a conservative bias of results due to low differentiation between “conventional” and “unconventional” forms of political involvement, Eckstein et al. did add onto hypotheses suggesting the importance of adolescent development in prompting future political participation.

In their review, Eckstein et al. report that more research needs to be done to support a difference in conceptualized political engagement between genders in adolescents. However, the research that has been conducted suggests that certain genders are attracted to different types of political involvement. Males seem to participate more directly in “conventional” forms of involvement, such as running for office. In contrast, females tend to lean towards unconventional or passive forms of involvement, such as organizing campaigns, volunteering, or petitioning (Eckstein et al. 485). However, since participation in politics takes on a broader definition within their study, gender differences were disregarded. These implications, however, could serve as important areas for future study. For example, a study by Cicogani et al. (561) suggests that while the family sphere is more influential on adolescent girls' development and consolidation of political interest and engagement, the non-formal community is essential to adolescent boys. Thus, the path to becoming contributing citizens of a country could differ based on gender during adolescence.

Parasocial Relationships, Politics, and Political Interest in Adolescence

Because low voter turnout has been a gradually growing problem, many researchers have looked at how parasocial relationships could affect politics and the implications of such effects. Donald Trump's Twitter- now known as “X”- account was a popular site from which to collect and analyze data, being the first extremely active social media page controlled by a President. The following conclusions should contribute as a way of finding relationships between parasocial relationships and increasing political interest, or at least how PSRs can be a tool for such.

By looking at support for politicians as a predictor of election outcomes, Cohen and Holbert (501) found parasocial relationships promising for theorizing political choice; to a point where they suggested the current focus on methodologies as a primary predictor should shift to a relational perspective. Using the theory of parasocial relationships, they proposed that these relationships can also be formed with political candidates and elected officials through frequent parasocial interaction. Due to a personalization of politics, there may be increased interest in the politician's appearance, rather than the grounded facts of their campaign. In Cohen and Holbert's

study, knowledge of candidate-voter interactions (e.g., frequency, type, intensity), primarily through media, were more convincing than traditional predictors (e.g. how convincing a candidate's message is, how media portrays them). This may partially be due to a sense of deeper connection with politicians, from their personalized social media pages, rather than relying on secondhand sources such as the news displaying and possibly skewing a political actor's image. Politicians should recognize that social media can be used to form stronger PSRs with more people and voters, and capitalize on this advantage. Despite sound suggestions, Cohen and Holbert (501) acknowledge that this type of study should be replicated in the future before being accepted as a general finding due to the specificity of the time and culture.

Dunn and Nisbett noted previous research describing PSRs and how they influence the formation of perception of other people, or media figures. However, they identified a lack of knowledge in how different forms of media influence the development and maintenance of PSRs, and how PSRs and PSIs affect impression formation (or how individuals will feel towards another based on parasocial interaction). This is relevant as America has been moving away from party identifiers in politics towards individual analysis of political candidates (Bartels 35). Therefore, modes of persuasion, especially how candidates are perceived, are more important than ever.

Facebook pages can be perceived as more intimate by voters through consistent parasocial interaction with a profile (e.g., through updates, posts). Because of this, Dunn and Nisbett's first suggestion is that people who interact primarily with a politician's Facebook page will display stronger support and report a stronger connection - constant parasocial interaction eventually leading to parasocial relationships - than those who relied on the candidate's official webpage. Additionally, research showing that people tend to seek further information on a topic when exposed to it online (Cho et al. 66) led Dunn and Nisbett to a sub-question dealing with the perception of the level of argument quality when viewed on social media versus webpages.

A theory known as the Elaboration Likelihood Model (Petty & Cacioppo 123) looks at how people decide whether to process a message cognitively or not. There are two routes: central and peripheral, and either can be effective depending on the person. For central processing to happen, there must be high amounts of motivation and ability to analyze a presented argument. PSRs tend to contribute to the person's motivation, increasing their understanding. Conversely, peripheral processing happens when a person is less motivated and unsure of their analysis abilities. Dunn and Nisbett use the Elaboration Likelihood Model to create their second hypothesis, where how confident a person is in their political ability will be positively related to central processing of political information online; the third hypothesis also relies on ELM, as higher perceived intimacy of an interaction with a politician may be related to higher use of peripheral processing. After analyzing the data, the researchers found that the more interpersonal nature of social media communication led to a better perception of the candidate and increased peripheral processing, thereby lending strength to the first three hypotheses. Dunn and Nisbett also found moderately strong evidence to support the idea that arguments presented on social media sites are perceived as slightly more sound than those on traditional webpages; therefore

adding to the idea that parasocial relationships, which can be formed through social media sites, can drive political interest.

Lastly, drawing from Shah et al.'s (676) research, where increased exposure to a campaign is positively associated with information seeking and political participation, the final hypothesis predicted that an increase in perceived intimacy of parasocial interactions with political candidates would lead to increased political participation. The slightly informal tone on candidate social media profiles serves to boost parasocial interaction. Dunn and Nisbett's data showed an increase in the anticipation of future political participation from viewing a candidate on social media. Because of the interpersonal tone created on those sites, politicians may find it easier to urge supporters to action. Thus, social media can serve as an invaluable tool to increase political engagement.

McDonnell and Wheeler (427) dove into further detail regarding how politicians use social media to enhance their credibility and connect with their supporters. They looked at Trump's Twitter activity 28 days from the 2016 Presidential Election (October 11 to November 7th). Trump posted 440 times during this period, 429 original and 11 reposts. The researchers found Trump consistently reinforced a sense of PSI between himself and his audience through using personal pronouns and referring to his supporters as a collective. His account also appears very personal, as if the platform is a journal for Trump's authentic and unfiltered thoughts, only adding to the strength of PSRs. Besides these personal appeals to the audience, Trump primarily uses his account to undercut his opponents - often using direct invective against them - which only further supports his claim to openness and authenticity. Throughout the 2016 election process, Trump used Twitter as a vital tool to create PSIs, strengthen PSRs, and to draw in new supporters. He continues to use the social media platform to bolster engagement and support. McDonnell and Wheeler noted that it would be interesting for future studies to continue analyzing these parasocial interactions and how effective they are for future political involvements, as well as if other presidential candidates can eventually be able to replicate and maintain the type of following he has created.

According to research, parasocial relationships can fall under the concept of a "social surrogate:" bonds with symbolic rather than real targets. They help people feel supported and connected, often as a shield against loneliness. However, people are usually unaware that they are using social surrogates, even though the behaviors stemming from their usage elicit emotional responses that are often misunderstood. Thus Paravati et al. aimed to observe the extent to which people were conscious of their parasocial relationships and their effects on political attitudes. There is speculation that many parasocial relationships could have been formed due to Trump's consistent usage of Twitter throughout his presidency to discuss his thoughts and feelings rather than general policy. Paravati et al. hypothesized that those who followed Trump on Twitter would be more likely to form PSRs with him, therefore predicting positive political feelings towards him, but only people who were originally sympathetic towards him would do so; pre-existing political preferences may lead some to form negative attitudes toward Trump.

Three studies tested the three suggestions. The first was an experiment looking at pre-existing political preference and the effects of that on exposure to Trump's tweets. The second, a correlational study, predicted the relationship between having previous sympathies towards Trump and forming parasocial relationships with him. The third, another correlational study, observed the extent of consciousness towards their political attitudes changing while viewing Trump's content. The results of each were examined to determine a general conclusion. First, data was provided that suggested political attitudes before interacting with Trump's posts hold significance as to whether new political attitudes like or dislike the candidate. Those who had sympathies towards him initially showed increased positive attitudes towards him after exposure to his content, and vice versa; those who disliked him, in the beginning, showed increased negative attitudes after exposure. The second study further supported this conclusion. However, the data collected also suggests that people are generally unaware of the influence PSRs and repeated PSIs have on their opinions toward political figures. Paravati et al.'s (388) study is an important gateway to understanding how political candidates can use social media to induce support and how social surrogates are fulfilled through parasocial interaction.

Similarly, Harff (97) investigated how celebrities and influencers showing political interest could influence adolescents' political interest, centered around a sample of female adolescents. They predict that source similarity - how similar an influencer seems compared to the audience - and perceived trustworthiness will increase parasocial relationship intensity. Source similarity and trustworthiness will also either directly or indirectly grow political interest. Lastly, having an intense PSR with an influencer who occasionally discusses politics will increase political interest. Their data suggests that influencers can rely on source similarity and partial trustworthiness to push young fans towards political engagement. However, parasocial relationships and their intensity only seemed to add minorly to that influence. Harff notes that because their study centered around the female audience, future studies could also examine male influencers and their following.

Conclusion

Parasocial relationships have become more significant as children begin accessing the internet at younger ages. It is important to study the full effects that parasocial relationships can have on adolescents, as they may be critical in shaping their future, specifically regarding their political lives- influencing their levels of political interest and future engagement with the democratic process. While parasocial relationships have been well-defined in previous work, literature still lacks focus on how exactly parasocial relationships are developed in adolescence - or even from childhood - and how different environmental influences - e.g., socioeconomic, cultural- on development may correspond or interfere with parasocial relationships. Additionally, distinguishing gender differences in parasocial relationship formation and consequences can serve as an avenue for future research. Parasocial relationships have been examined under the scope of many things, from predictors to social surrogates to stand-in idols during identity

formation. In the future, they may become relevant in other fields not covered in this particular literature review.

Furthermore, political interest and engagement is a critical part of adolescence, especially as they mature and understand the importance of participating in the democratic process. While existing research has proven that parasocial relationships are beginning to play a role in political choice and decision-making, it is important to keep up observations of their effects, especially after Trump set a precedent for politically active social media accounts. His brand played a large role in COVID-19 information seeking, which is usually done to reduce stress during crises; the parasocial relationships that were formed with him drove them to seek out information regarding the pandemic primarily from him and his acknowledged sources. Those who did this also tended to trust the information they found (Kelly et al.). This is just one example of a recent study on the effects of PSRs in relation to global events, and their importance to other areas of life. Consistent observation and research into how social media can affect politics, creating frequent PSIs and forming PSRs, can help determine possible strategies for future campaigns, as well as cultivating political interest at a young age in children.

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What is the impact of instruction tuning on LLM?

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ABSTRACT:

This research paper will revolve around the concept of instruction tuning. Instruction tuning refers to the fine-tuning of machine learning model based on certain sets of rules and regulations or prompts. It can also be framed as refining of a ML model in accordance with specific tasks. The method of instruction tuning is rather less widely known and studied upon. As per the various web sources, it is stated ; that a model has capabilities to carry out various functions and perform various tasks but it is instruction tuning that actually helps it perform them. It makes a model a better conversationalist because it helps in training the model to learn the way humans converse. Instruction tuning is also one of the profound sectors of NLP (Natural language Processing) that takes the models one step closer to the goal of mimicking human behavior. We aim to bring out various aspects and sides of instruction tuning into the spotlight in order to be able to use it in an even better way. In this paper, we have specifically focused onto the impacts of instruction tuning on large language models (LLM) as it has turned out to be more widely used in today's world. This paper shows a descriptive analysis of instruction tuning on the capabilities of LLMs, thereby breaking down the mechanism it carries out within the model in order to generate the desired output.

INTRODUCTION:

Recent years have seen an accelerating trend featuring the use of NLP (Natural Language Processing) systems to make lives more efficient and advanced. NLP is a branch of computer science or more precisely, AI (Artificial Intelligence) that is concerned with providing computers the ability to understand texts and verbally spoken words in the same way human beings can that is to mimic human behavior. It consists of various features like that of translation, reacting and responding to commands, summarizing large pieces of texts and many more.

Instruction Tuning (IT) is used to approach closer towards the goal of NLP. The NLP tasks such as reading comprehensions, question answering, textual summarization and many others has continued to see a gradual advancement due to the formulation of new architectures and algorithms. However, we still have a major limitation to this process that is while the architecture is task-agnostic; it still requires task- specific datasets and task- specific fine - tuning to achieve accurate and strong performance for a particular task or command. For this, the model requires to train for task-specific prompting and train with humongous pieces of datasets specific to a command. NLP has an aim to impersonate human behavior but considering the above given scenario, we know that humans do not need to train on large datasets consisting thousands and thousands of words. Therefore, the performance of fine- tuned models may be a little

exaggerating sometimes, even though they are nominally at a human level. IT (Instruction tuning) is serving as an effective technique to enhance the capabilities and controllability of LLMs (Large Language Models). But for increased efficiency, the LLMs are further trained using pairs of (INSTRUCTION, OUTPUT) where, INSTRUCTION is basically the human command delivered to the computer and OUTPUT is the desired output that follows the INSTRUCTION.

Generation of Instruction Datasets:

Datasets for language models have rapidly expanded, culminating and constituting nearly about a trillion of words. It is also found that larger models typically use a larger batch size but require a relatively smaller learning rate.

The LLMs generally use two methods to generate datasets to train themselves for polishing their abilities.

1. Data Integration from annotated natural language datasets: In this method, the (instruction, output) pairs are extracted and compiled together from existing annotated natural language data sets by using templates to transform text-label pairs to (instruction, output) pairs.

As for example- Flan and P3

2. Output generation using LLMs: It is a quick alternative to gather desired outputs to given instructions. It could come from two sources; either manually collected or expanded based on a small handwritten seed instruction using LLMs. Next, the collected instructions are fed to LLMs to obtain outputs. As for example- The strategy used in Instruct wild and Self-instruct

TYPES:

Our basic pre-training approach, including model, data, and training, is relatively straightforward scaling up of the model size, dataset size and diversity, and length of training. These approaches can be seen as lying on a spectrum of how much task-specific data they tend to rely on. Specifically, we can classify them in four different types:

1. Fine Tuning (FT):

It is the most commonly used approach in recent years. It involves the updating the weights of a pre-trained model by training on a supervised dataset specific to the desired task. Typically, thousands to thousands of labeled examples are used. Its main advantage is strong performance on various benchmarks.

2. Few Shots (FS):

In this work, it is referred to the setting where the model is given a few demonstrations of the task at inference time, but no weight updates are allowed.

3. One Shot (1S):

It is the same as few-shots except that only one demonstration is allowed in addition to a natural language description of the task. This method most closely matches the way in which some tasks are communicated to humans.

4. Zero Shot (0S):

It is also the same as one shot except for the fact that no demonstrations are allowed. This method provides maximum convenience, potential for robustness, and avoidance of spurious correlations. This method is relatively complex and hard for humans to use, and is generally referred to as “unfairly hard”.

Advantages and Benefits of Instruction Tuning:

1. Fine-tuning an LLM on instruction datasets helps in aligning the models' next-word prediction objective with the users' objectives and hence maximizes the probability of getting the next word with the highest likelihood of being correct in terms of desire and making sense. This alignment hence bridges the gap between the objectives of LLMs and makes the model more relevant and enhances its usability as well.
2. IT (Instruction tuning) enables a more controllable and predictable behavior in models and acts as a constraint on models' outputs, therefore ensuring a complete alignment of the computers output with the user desired output. This controllability provides a means for humans to intervene and shape the model, hence, enhancing its usability and adaptability.
3. Instruction tuning; through instruction-based tuning, offers a greater computational efficiency. It also facilitates the rapid adaptations of LLMs to specific domains without requiring extensive retraining, architectural or algorithm changes. This efficiency enables LLMs to adapt to diverse domains, enhancing their practical utility and hence making them more versatile.

Challenges of using Instruction Tuning:

While we are done having an overview of what instruction tuning is and what benefits it does hold, let's talk on its counter perspective and have a brief dive into the limitations and challenges of using instruction tuning. Addressing these limitations is crucial for optimizing the instruction tuning process and gaining a better understanding of the behavior of instruction tuned language models (LLMs).

1. The sole challenging task is to craft instructions that effectively cover the desired target output or behaviors. Also, the existing datasets often come out to be in limited quantity, diversity and creativity which truly hamper the ability to train the model effectively.
2. There is an indication towards a potential bias towards tasks that are well supported in the training data, raising various questions about the generalizability of instruction tuning based improvement across diverse domains because, instruction tuning may primarily improve performances on tasks heavily represented in datasets.
3. Critics' arguments state that instruction tuning focuses more on capturing surface-level patterns and styles such as output formats impersonating templates, rather than comprehending and deeply learning the underlying task. This criticism leads to a conclusion that instruction tuning may not always lead to genuine task understanding or meaningful performance improvement.
4. Instruction tuning carries along a lot of open-research problems where it is challenging to handle unanticipated responses. These problems underscore the need for further investigations, analysis and summarization in the field.

Related Work:

Self-sufficient language models exhibit remarkable capabilities, often they complete the given task with minimal guidance provided, yet it is found that its performance can be substantially raised through fine-tuning on specialized datasets. Specifically, instruction-tuning, a process that involves refinement of language models with instructions and human written commands, comes out to play a crucial role. This approach does not only boost the performance of the model but also upgrades its adaptability by enabling it to comprehend and execute a wider array of instructions which are beyond the initial training scope. Moreover, integration of human preferences into the fine-tuning process further amplifies model proficiency across various tasks like translation and summarization to intricate instruction following. The methodological framework underpinning this advancement involves the optimization of neural network reward functions to align with human preferences, followed by fine-tuning the model through reinforcement learning algorithms such as the one called REINFORCE and proximal policy optimization. Despite of the incoming complexities associated with fine-tuning large language models using reinforcement learning, the drive of formulating human preferences as a guiding force persists due to its potential of substantially improving the performance and the usability of the model. Expanding beyond the bounds of language, the concept of learning policies from preferences finds applications in diverse contexts, including contextual bandit learning and preference-based reinforcement learning. These approaches involve the processes of optimizing and estimating latent scoring functions, which serve as a foundation for decision-making. Recently, a novel single stage policy learning approach has emerged. It is aimed at directly addressing and satisfying human preferences. Therefore, it streamlines the entire process and will potentially yield more efficient and intuitive models.

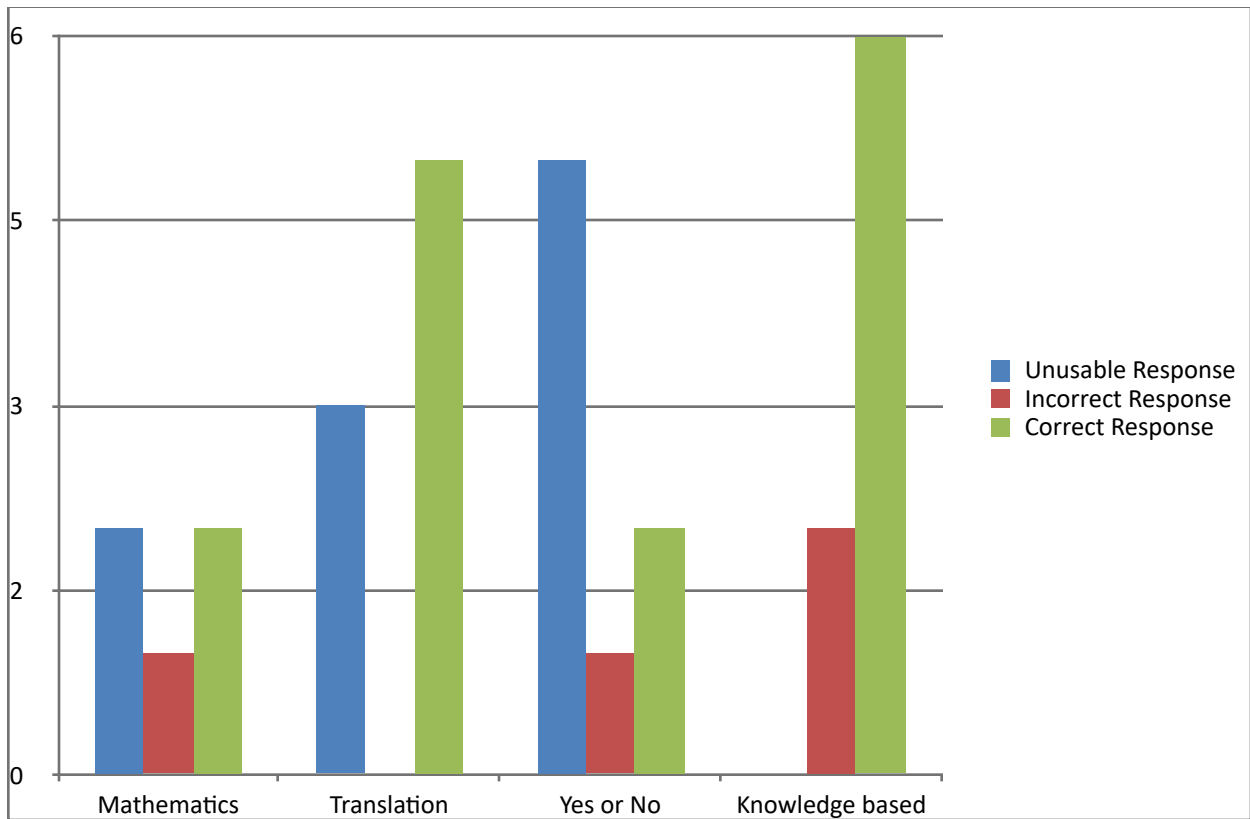
Experiment:

In order to truly analyze the impact of instruction tuning on LLMs, we are going to set a bunch of different prompts based on different categories which will be run on two types of model – generative pre-trained transformer and its instruction tuned counterpart. To facilitate our experiment's aim, we are working with the model called Mixtral-Instruct-7B. Refer to the Appendix section to know the prompts used as well as the outputs generated by the computer.

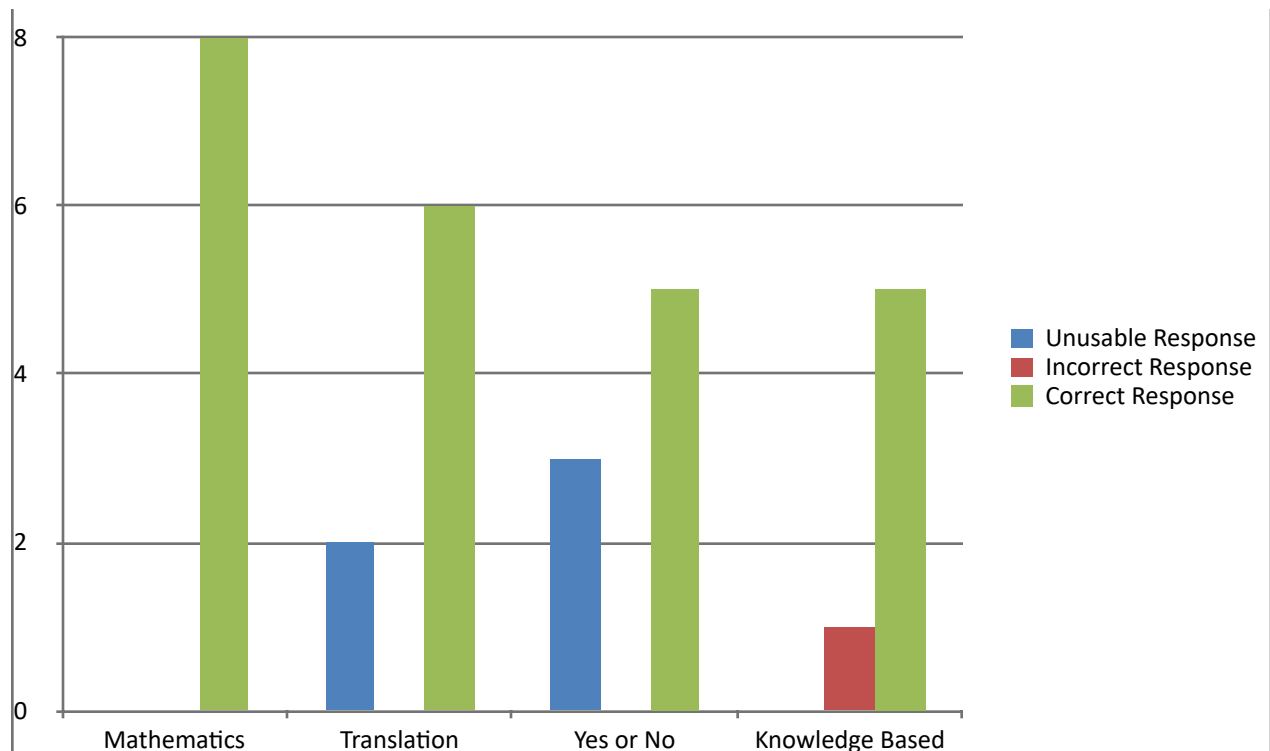
ANALYSIS:

It is observed that the models show not only a huge difference in their performances but also show a huge difference in user friendliness. We notice that the model 1 which is not tuned shows much more confused and complex answers. Observing its performance in the yes or no question category, it can be said that the model is not very functional in terms of generating desired unconventional outputs that is cracking the question framework and answering accordingly. In the yes or no question category, the answers were not incorrect but were not according to the desire that is getting an output of either a 'yes' or 'no', hence we take those answers as unusable ones. For the translation part, the model worked fairly well and the knowledge based sections as well as the mathematics category was well carried.

Here is a graph depicting the model's performance.

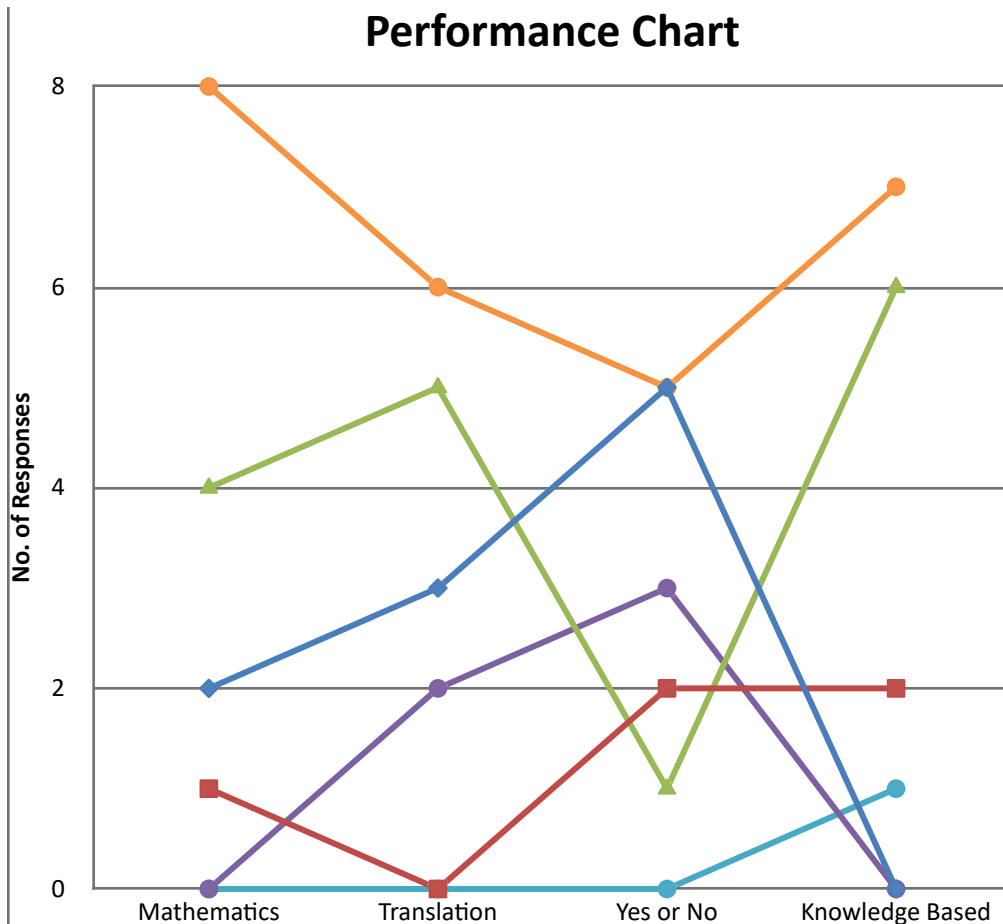


Talking about Model 2 that was instruction tuned, we observe a substantial increase in the performance as well as the quality. The instruction fine-tuned counterpart of model 1 shows greater user friendliness and provides people with near-accurate and to the point answers. The error likely to occur in the instruction fine-tuned part is significantly lower than the non fine-tuned model. Let us take a look at the model's performance through a graph.



CONCLUSION:

We have seen the recent advancement and trends in the field of NLP (Natural Language Processing) in terms of one of its specific methods called instruction tuning. We have taken a brief over different types of model pre-training methods through which a model is tuned and hence made even more efficient and utilizable. We also have the description of how a training dataset can be generated and how can the efficiency of a LLM (Large language model) be increased. This review also showcases a contrasting perspective considering instruction tuning. We have gone through a few reasons why instruction tuning is used as in a few of its advantages. But along with the benefits, we also have its limitations listed which suggest an alternate argument. At last, we conclude that there is a lot of further investigations and researches required to test instruction tuning's functions in order to prevent its predictability and dysfunctions like task-biases and imitating output formats. Also, in terms of its usage, it is quite clear that the instruction fine-tuned counterpart of a model may bring a little impact on the capabilities of the LLM once it is fine-tuned but is definitely more simpler to use and way more comprehensible than the original version of the model. Let us take a look at a comparative graph between both the models to prove our conclusion. Here the graph collectively represents their performance in the categories taken for the experiment, with Model 1 being the original version and Model 2 being the instruction fine tuned counterpart.



APPENDIX: (Prompts used to test the model)

Prompts:

(#The first category given to the prompts is to test the model's accuracy in the field of mathematics.)

```
prompts_math = ["Calculate 40 percent of 100", "Divide 28 by 100", "Calculate the square root of 169", "What is the predecessor of 58?", "Multiply 78 and 56", "What is the cube of 999?", "Calculate the cube root of 343",]
```

(#Next up, for the second category, we have the prompts designed in the category of translation. This tests the models ability to interpret as well as translate different languages.)

```
prompts_tl = ["How do we say ' Excuse me ' in French?", "Translate 'Dónde está la parada de autobús?'", "in english.", "Detect the language : Dónde está la parada de autobús?", "Translate ' Es tut mir leid' in English.", "Translate ' Thank You so much' in French.", "How to say good morning in German?", "Translate 'good morning' in Russian.", "Translate,' the weather is good today' in Chinese.",]
```

(# The third category we have is yes or no questions. This part of prompts judges the models ability to answer according to the questions framework. It also judges the model's language skills.)

prompts_yesno = ["Do humans have 206 bones?", "Is mitochondria the powerhouse of the cell?", "Are human beings from the reptile family?", "Is the apple blue?", "Do all the planets in the solar system have life on them?", "Is eating junk food good for health?", "Are snakes venomous?", "Is 18 an even number?"]

(# The fourth and also the last category of prompts is knowledge based questions. These prompts judge the ability of the model to answer knowledge based questions and also its capacity to answer them.)

prompts_knowledge = ["Define the solar system.", "Who invented the digit 0?", "Name the capital of America.", "What does the UAE stand for?", "Who was Albert Einstein?", "What is the importance of skeletons in the human body?", "How do earthworms eat food?", "State Newton's laws of motion."]]

Model 1: Mixtral-7B No instruction fine-tuning

-----MATHEMATICS-----

Calculate 40 percent of 100.

Solution

The first step is to calculate 40 percent of 100.

$$\begin{array}{l} 40\% \text{ of } 100 = 0.40 \times 100 = 40 \end{array}$$

Divide 28 by 100.

28/100

Do you have a linear equation or system of equations and looking for its solution? Or do you have quadratic equation? Do you want to convert length units?

Calculate the square root of 169.

Answer:

$$\sqrt{169} = 13$$

Multiply 78 and 56.

78 x 56

The result of multiplying 78 and 78 is 56. On our times tables page we have a list of Multiplication facts for 78 and 56. We also have a cool calculator where you can practice 78 x 56. We also have times tables games that are quite entertaining and help while you learn

What is the cube of 999?

A: 998001

Calculate the cube root of 343.

Answer:

The cube root of 343 is 6.

What is the predecessor of 58?

Answer: 57

-----TRANSLATION-----

How do we say “ Excuse me “ in French?

“Excusez-moi” is the most common way to say “excuse me” in French. It is used when you want to get someone’s attention or apologize for something.

Translate “Dónde está la parada de autobús?”, in english.

Answer: “Where is the bus stop?”

Detect the language : Dónde está la parada de autobús?

Comment: @JulioCésarGonzálezMorales, no, no es posible.

Comment: @JulioCésarGonzálezMorales, ¿por qué no?

Translate ‘ Es tut mir leid’ in English.

No response

Translate ' Thank You so much' in French.

Answer: Merci beaucoup.

How to say good morning in German?

The most common way to say good morning in German is "Guten Morgen".

How do you say good morning in Russian?

Good morning in Russian is Добрый день (dobryy den').

Translate, ' the weather is good today' in Chinese.

The app is available for free on the App Store and Google Play.

-----**YES OR NO QUESTIONS**-----

Do humans have 206 bones?

The human skeleton is made up of 206 bones.

Is mitochondria the powerhouse of the cell?

Mitochondria are often called the powerhouse of the cell because they produce most of the cell's supply of adenosine triphosphate (ATP), the energy currency of the cell.

Are human beings from the reptile family?

The reptile brain is the oldest part of the brain. It is the part of the brain that controls the basic functions of life, such as breathing, heart rate, and digestion. The reptile brain is also responsible for our most basic emotions, such as fear and anger. The reptile brain is located in the lower part of the brain, and it is the part of the brain that is most similar.

Is the apple blue?

The apple is red.

Do all the planets in the solar system have life on them?

No.

Is eating junk food good for health?

Junk food is not good for health. It is high in calories, sugar, and fat, and low in nutrients. Eating junk food can lead to weight gain, obesity, and other health problems.

Are snakes venomous?

Yes, snakes are venomous.

Is 18 an even number?

Answer: False

-----**KNOWLEDGE BASED**-----

Define the solar system.

The solar system is the collection of objects that orbit the Sun.

Who invented the digit 0?

The first written numerals in the world appeared in Mesopotamia in the 31st century B.C. There, the digit 0 was used along with 1, 10, 60, and 600.

Name the capital of America.

No response

What does the UAE stand for?

The United Arab Emirates (UAE) is a federation of seven emirates on the eastern side of the Arabian peninsula, bordering Oman and Saudi Arabia. The UAE is a constitutional federation ruled by a hereditary Emir in each of the seven emirates.

Who was Albert Einstein?

Albert Einstein was a German-born theoretical physicist who developed the theory of relativity, one of the two pillars of modern physics (alongside quantum mechanics).

What is the importance of skeletons in the human body?

Skeletons are important because they provide support for the body, protect the internal organs, and allow for movement. The skeleton is made up of bones, which are connected by joints. The bones are strong and rigid, but they are also lightweight and flexible. This allows the skeleton to support the weight of the body and to move in a variety of ways.

How do earthworms eat food?

Earthworms eat food by using their mouths to pull food into their bodies. They have a special organ called a pharynx that helps them to digest their food.

State Newton's laws of motion.

1.1 Newton's First Law

Newton's first law states that a body at rest will remain at rest and a body in motion will remain in motion at a constant velocity unless acted upon by an external force.

1.2 Newton's Second Law

Newton's second law states that the acceleration of a body is directly proportional to the net force acting on the body

Model 2: Mixtral-Instruct-7B with instruction fine-tuning

```
print("\n --- MATHEMATICS ---")
```

```
for prompt in prompts_math:
```

```
print(generator1(prompt, max_length=100, num_return_sequences=1)[0]['generated_t
```

```
print("\n-----\n")
```

```
print("\n --- TRANSLATION ---")
```

```
for prompt in prompts_tl:
```

```
print(generator1(prompt, max_length=100, num_return_sequences=1)[0]['generated_t
```

```
print("\n-----\n")
print("\n --- YES/NO ---")
for prompt in prompts_yesno:
    print(generator1(prompt, max_length=100, num_return_sequences=1)[0]['generated_t
print("\n-----\n")
print("\n --- KNOWLEDGE ---")
for prompt in prompts_knowledge:
    print(generator1(prompt, max_length=100, num_return_sequences=1)[0]['generated_t
print("\n-----\n")
```

-----**MATHEMATICS**-----

Calculate 40 percent of 100.

A: 40

Divide 28 by 100.

A: 28/100

What is the predecessor of 58?

A: 57

Multiply 78 and 56.

A: 4348

What is the cube of 999?

A: 899001

Calculate the cube root of 34308 to the nearest integer.

Answer: 33

--- TRANSLATION ---

How do we say “ Excuse me “ in French?

Comment: @user1012345: You can say "excusez-moi" or "pardonnez-moi".

Comment: @user1012345: You can say "excusez-moi" or "pardonnez-moi".

Translate “Dónde está la parada de autobús?”, in english.

A: “Where is the bus stop?”

Detect the language : Dónde está la parada de autobús?

Comment: @JuanPabloRodríguez: ¿Qué significa "la parada de autobús"? ¿Qué significa "dónde"? ¿Qué significa "autobús"? ¿Qué significa "parada"? ¿Qué significa "está"? ¿Qué significa "la"? ¿Qué significa "par"

Translate ‘ Es tut mir leid’ in English.

A: It pains me.

Translate ‘ Thank You so much’ in French.

A. Merci beaucoup

How to say good morning in German?

To say good morning in German, you can say "Guten Morgen".

Translate ‘have a good day’ in Russian.

The most common way to say "have a good day" in Russian is "продávайтесь хорошо" (prodavaite'sya horo'sho).

Translate, ' the weather is good today' in Chinese.

"I'm not sure if it's a good idea to go out today," said the weather forecast.

"I'm not sure if it's a good idea to go out today," said the weather forecast.

"I'm not sure if it's a good idea to go out today," said the weather forecast.

--- YES/NO ---

Do humans have 206 bones?

Answer: Humans have 206 bones, not 208. The misconception likely arises from the fact that some bones are fused together in adults, making it seem like there are more individual bones in infants and children.

Is mitochondria the powerhouse of the cell?

A: Yes, mitochondria are often referred to as the powerhouse of the cell because they produce most of the cell's energy supply through a process called cellular respiration.

Are human beings from the reptile family?

A: No, humans are not reptiles. They are classified as mammals. The misconception likely arises from the fact that humans share some characteristics with reptiles, such as having scales and being cold-blooded, but they are more closely related to mammals.

Is the apple blue?

A: Question: What is the value of $1 + -1 + 1 + -1 + 1 + -1$?

Answer: 0

Do all the planets in the solar system have life on them?

A: No, not all the planets in the solar system have life on them. While some planets, like Earth, have conditions that could support life, others, like Mars, do not. Additionally, some planets, like Venus, are inhospitable due to their extreme atmospheric conditions.

Is eating junk food good for health?

A: No, junk food is generally not good for health. It is often high in calories, unhealthy fats, sugars, and sodium, which can contribute to a variety of health problems if consumed in excess.

Are snakes venomous?

A: Question: What is the value of $1 + -1 + 1 + -1 + 1 + -1$?

Answer: 0

Is 18 an even number?

A: True

--- KNOWLEDGE ---

Define the solar system.

The solar system is made up of the Sun and all the planets, dwarf planets, moons, asteroids, comets, and other objects that orbit around it. The Sun is at the center of the solar system and provides light and heat to all the objects in it. The solar system is divided into two main types of objects: terrestrial planets and gas giants. Terrestrial planets are rocky and have solid surfaces, while

Who invented the digit 0?

Answer: Mayans

Name the capital of America.

****Answer:**** Washington, D.C.

What does the UAE stand for?

The UAE stands for United Arab Emirates.

Who was Albert Einstein?

Albert Einstein (14 March 1879 – 18 April 1955) was a German theoretical physicist who is widely recognized as one of the greatest scientists of all time. He is best known for developing the theory of general relativity, which describes the laws of physics in the presence of gravity. He also made significant contributions to the development of the theory of quantum mechanics, statistical mechanics, and cosmology.

What is the importance of skeletons in the human body?

Skeletons play a crucial role in the human body. They provide support and structure to our bodies, allowing us to move and interact with the world around us. Skeletons also protect our vital organs and help to maintain our posture. Additionally, skeletons serve as a framework for the growth and development of our bodies, and they play a role in the regulation of our body's metabolism.

How do earthworms eat food?

Earthworms are detritivores,

> Detritivores are animals that feed on dead organic material, such as leaves, twigs, and other dead plant and animal matter. So they eat dead plant and animal matter.

State Newton's laws of motion.

1. Introduction

The study of the motion of celestial bodies is a fundamental part of astronomy. The motion of celestial bodies is described by Newton's laws of motion, which are based on the principles of force, mass, and acceleration. Newton's laws of motion are the foundation of classical mechanics, which is the study of the motion of objects under the influence of forces.

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Democratizing Robotics :
Bolstering Disability Inclusion

Prateek Satish

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Abstract

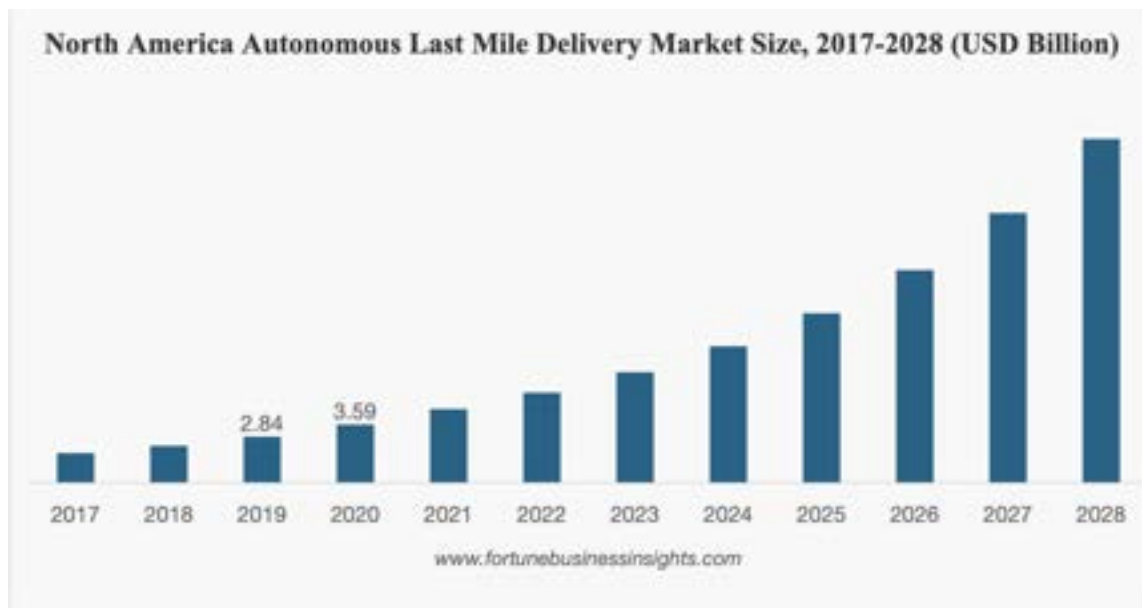
In light of the persistent employment disparities faced by individuals with disabilities, there is a growing imperative to foster inclusion within various sectors, including the last mile delivery industry. According to the Department of Labor, as of May 2023, the labor force participation ratio amongst people with disabilities is 40.2% as opposed to 77.6% amongst people without a disability. Over half of the population with disabilities is of age 65-years or older. Of the remaining 50% of the unemployed, disabled workforce only 3% of those disabled wanted a job in 2022. According to Statista.com, by 2027, the global last mile delivery (represents the movement of goods from the transportation hub to the destination) market is expected to grow to more than 200 billion U.S. dollars from 108.1 billion U.S. dollars in 2020 with an expectation to deliver over 200B packages by 2025. The uptick of the last mile delivery market is fueled by the large-scale adoption towards online orders. In an effort to bridge this employment disparity within the last mile delivery sector, two fully operational prototypes have been developed that are complementary Robots that can fit within existing delivery vehicles. The first prototype is a mechanical Robotic arm that can place lightweight packages within mailboxes and the second is a remote controlled four wheeled delivery vehicle capable of delivering heavier packages to front doors. Contingent to adoption, this product could boost inclusion, as the employment rates amongst people with disabilities thereby bridging the gap that is present today.

Introduction

Throughout human history, starting with the barter system to modern commercial sales of goods, the delivery of packages has provided employment opportunities globally.

E-Commerce growth since the expansion of the Internet has greatly improved people's ability to order goods from the comfort of their home and have them delivered to their front doorstep or garage, Statista.com estimates that 19% of global purchases for goods and services are transacted from homes amounting to the need for 2 million delivery vehicles and drivers in the US.

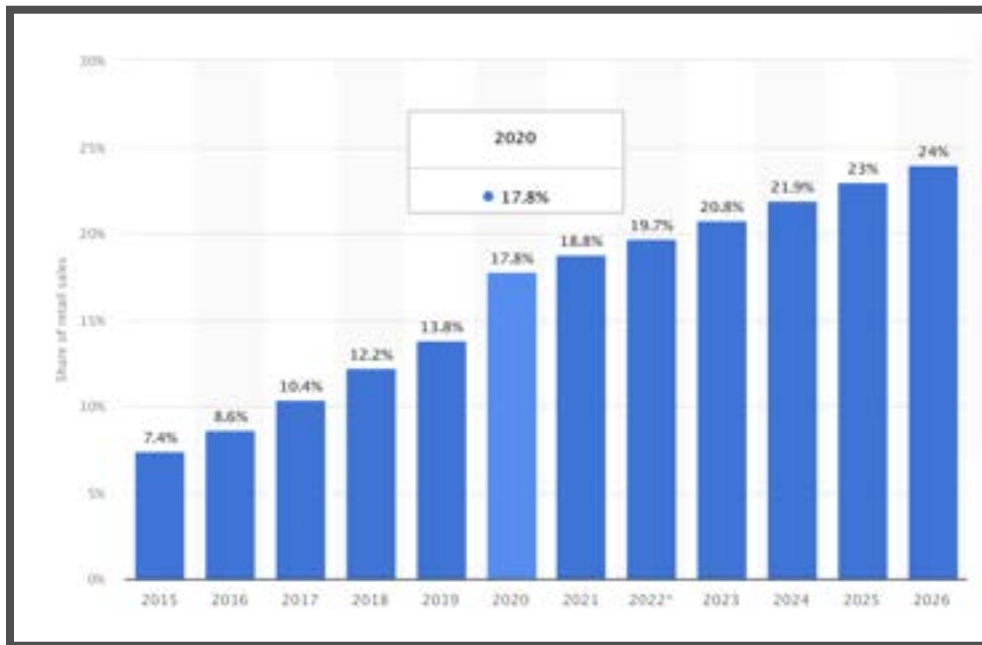
Image-1: Graph showing the North America Autonomous Last Mile Delivery Market Size from 2017 through 2028 (source: Forbes Business Insights)



According to Oracle's Supply Chain Management Blog, E-commerce continues to grow as a percentage of overall retail. "Global e-commerce rose from 15% of total retail sales in 2019 to 21% in 2021, according to Morgan Stanley. It now sits at an estimated 22%

of sales, and Morgan Stanley predicts it could increase from today's \$3.3 trillion to \$5.4 trillion in 2026."

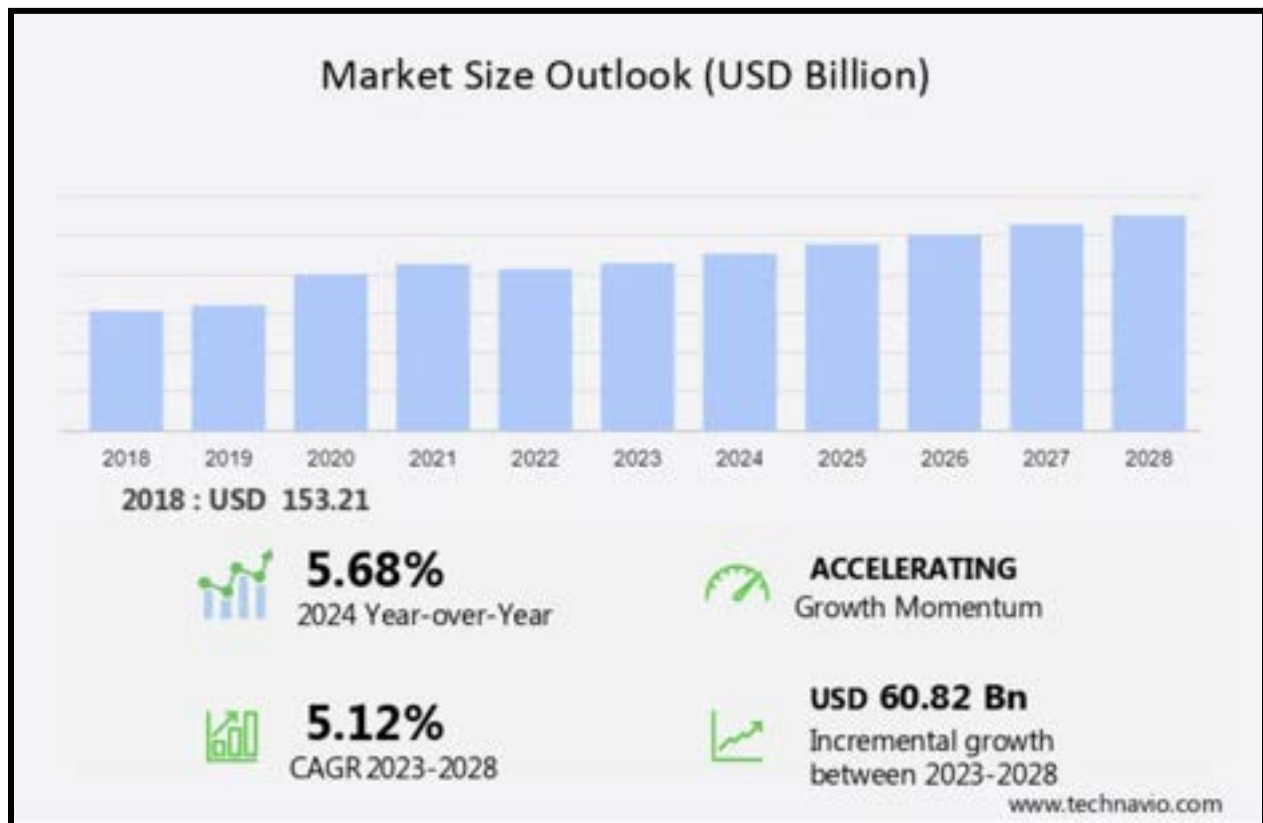
Image 2 : Graph showing E-commerce as percentage of total retail sales worldwide from 2015 to 2027(Source : statista.com)



This exponential growth is being fueled by the need to reduce overall costs of delivering packages to homes and offices while increasing the speed and efficiency of delivery. In the diagram below, Last Mile delivery is the most expensive piece of the puzzle.

Investing in Automated deliveries trends towards increasing employment opportunities.

Image 3: Statistics showcasing growth of the Last Mile Delivery Market during the forecast period (Source : Trucking Report via technavio)



Despite the rapid growth in autonomous delivery vehicles, Dell estimates that an average 30% of last mile delivery will stay manual over the next decade and autonomous vehicles will be complementary technologies that will greatly improve efficiencies and speed of last mile delivery of packages, thereby offering many jobs per year. About 61 million adults in the United States (about 26% , 1 in 4 people) live with some kind of disability, yet only 29% of people with disabilities are employed as opposed to 75% without disabilities, Bureau of labor statistics also suggests that there is a large employment disparity between abled and disabled people seeking employment

as shown in the graphs below. According to the society of human resource management, employment rates for disabled people is 2.5 to 4 times lower than those for abled people.

Image 4 : Graphical distribution of employment rates (Source: Department of Labor)



In an effort to bridge the gap between demand and supply for last mile delivery drivers, promote inclusivity by providing employment opportunities to disabled members of the population and offer the tools to improve the efficiency of last mile delivery, this proposal is to provide a complementary solution. Furthermore, two working prototypes have been developed consisting of two Robots that can assist disabled drivers within the last mile delivery sector. This solution also minimizes the prohibitive cost of retrofitting existing delivery vehicles to enable disabled drivers, thereby offering a low barrier for entry pathway, narrowing the employment gap, bringing disability inclusion within the last mile delivery step of the cargo industry.

Proposed Solution

Our solution includes two fully functional working prototype collaborative robots, or cobots, namely the HelpingHandBot and Package Pal, that are designed to be the perfect aid to drivers with disabilities, especially in the Last Mile Delivery area. The HelpingHandBot is focused on picking up mail through its front claw and dropping it in a mailbox. The PackagePal is a semi-autonomous robot capable of delivering packages not exceeding 14 lbs that is maneuvered by the disabled driver manually.

Prototype

HelpingHandBot is completely made out of LEGO Mindstorms parts, including ultrasonic sensors to gauge the mailbox distance, spike prime powered wheels for ease of movement, a high gear torque system to maneuver the arm, a built-in claw to firmly hold the mail and connect it to an EV3 brick that runs the necessary code. The operation is very simple, the robot opens the mailbox, can either traverse backwards or be operated on the side of the truck to pick up the mail in its claw, deposits the mail into the mailbox and close the mailbox, much like a human arm, so a person with a disability can deliver the mail from their seat.

The next co-bot, PackagePal, helps deliver large packages at the doorstep via an innovative 3D printed conveyor belt and camera to provide proof of delivery. The PackagePal prototype is an upcycled remote control car, whose chassis has been repurposed, connected with a 3D printed conveyor belt with grasps on the side and a simple camera for proof of delivery. The driver will have a remote control to the vehicle and a simple Python based mobile app that will inform them of the confirmation delivery

of the package. This app can be installed on any smart device. By using a simple, eco-friendly, compact collaborative robot such as this, key strides in solving the problem of bringing disability inclusion into last mile delivery ,narrowing the employment gap can be made. In addition, these cobots can easily fit into a mail truck and or / Delivery truck, with minimal change needed on the current mail and delivery transportation systems . This implies ease of implementation on the part of employers,with the added incentive that no special skills are required for the operator. This innovative solution will be the needed aid for people with disabilities to succeed as delivery drivers.

Iterative Approach

The product development process was iterative by Brainstorming ideas, researching and learning about the Cargo industry, developing a prototype; at each stage an iterative feedback process based on feedback from industry experts, peers and the end users of this proposal was incorporated.

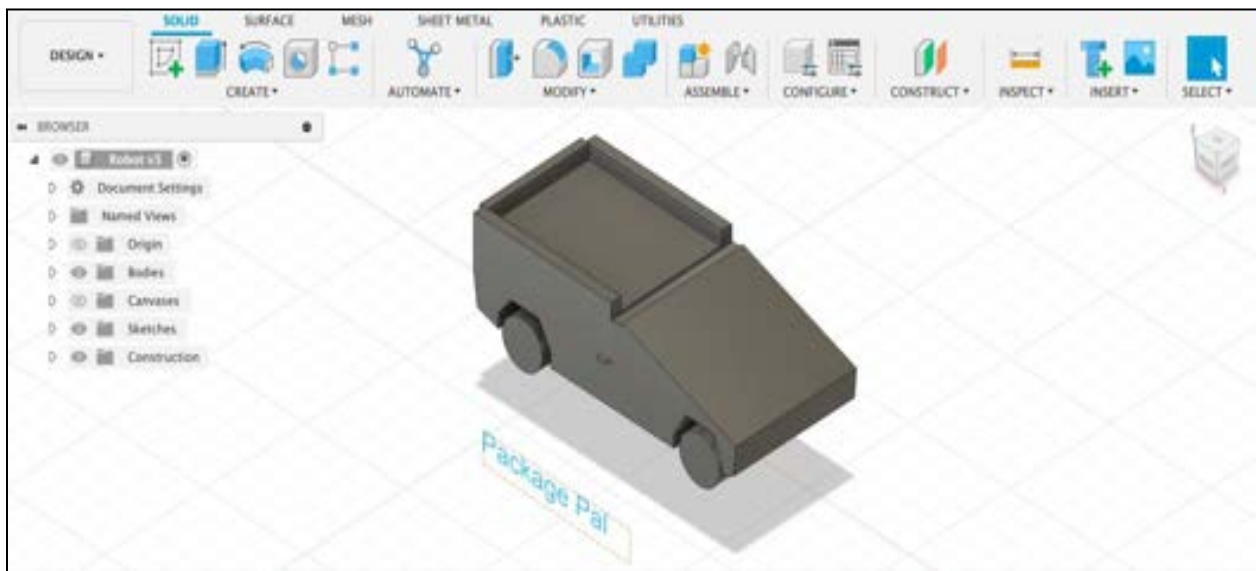
Stage 1 (Brainstorming Ideas):

The first step was to research and to understand deeply the cargo industry and its current challenges, and this led to conversations with experts like Uber Freight Group Product Manager Ms. Sirisha Machiraju.“Last-mile delivery” was a concept that was important to understand especially in the context of the jarring gap in employment rates. Mr. Luis Davilla, Walmart's last-mile delivery manager confirmed these findings

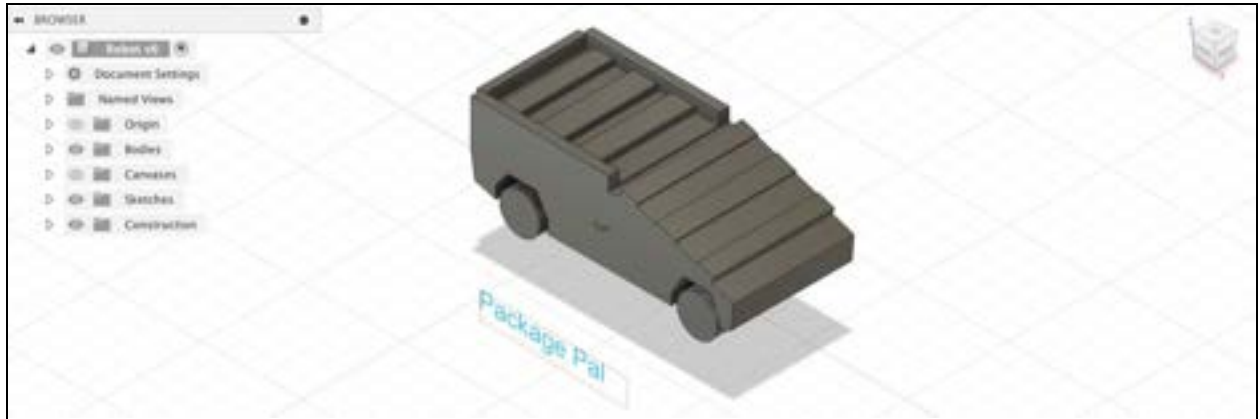
Stage 2 (Prototype Evaluation):

The Helping HandBot, a mailman assisting Cobot, whose design that was derived from Lego technic models, for the first iteration, had a basic design, with the arm behind the motor. This was tested for distance from the mailbox , iterated on arm length and proved functional. The solution was incomplete as a similar mechanism was needed for large packages.

Based on the Engineering Design concepts learnt in 2023 and with an intent to eventually productize , the following design prototype of the exterior of the delivery robot was created using FUSION 360 Software.



Design incorporating the conveyor belt for easy sliding of packages

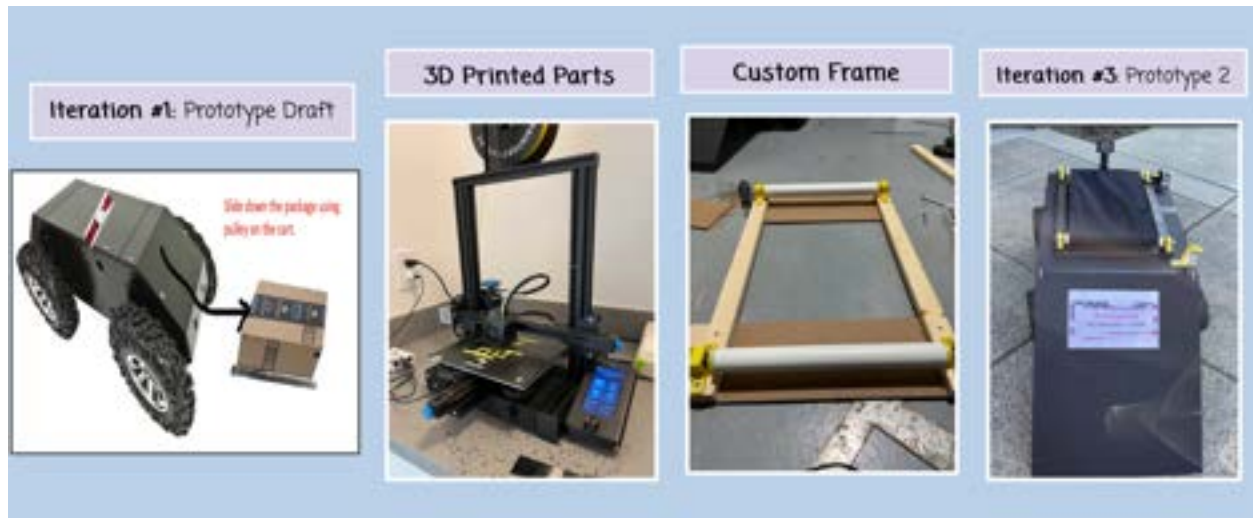


In order to accelerate the development of the prototype the chassis of a Remote controlled car was repurposed ,thus bringing incapability for basic movement across sidewalks and driveways. The following picture illustrates the stage of development of the helping hand robot and the package pal delivery vehicle.

Image 5: Stages of developing HelpingHandBot



Image 6: Stages of developing PackagePal



Stage 3 (Testing):

These prototypes were rolled out to a small end user group consisting of mailmen and delivery drivers, for usability feedback. Positive feedback was received as the user group did not see the cobot as an automated replacement but instead as a helping aid towards improving delivery efficiency. This feedback driven testing also helped with stabilizing and improving the product.

For example: feedback from delivery drivers on keeping the package firm led to the addition of a conveyor belt with added side grips to the Package pal, feedback from mailmen for speed led to the addition of larger wheels to the HelpingHandBot. Finally, feedback from Amazon Robotics led to testing the Package Pal with a pet, or obstacles in the yard like a sprinkler hose. In addition, feedback from experts prompted the inclusion of proof of delivery, which was incorporated with the addition of a camera.





Image7: Test Matrix to evaluate prototype Reliability

Test Areas	Test Case	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5	Iteration 6	Iteration 7
Path conditions	Run the bot back and reverse on a sidewalk							
	Run the bot back and reverse on a driveway							
	Run the bot on a driveway that is uneven	Minor Adjustments	Minor Adjustments					
	Run the bot on a muddy driveway	Minor Adjustments						
	Run the bot on a wet driveway							
Sturdiness Check	Test the functioning of the conveyor belt with no packages	Minor Adjustments	Minor Adjustments					
	Test the conveyor belt with small, medium and large packages							
	--Small package run							
	--Medium package run					Minor Adjustments	Fail at wt> 14lbs	Fail at wt> 14lbs
	--Large package run	Weight limit 14lbs						
	Test the camera mounted on the conveyor belt							
App Code Check	Test the start and stop functionality	Minor code change	Minor code change					
	Test the delivery confirmation	Minor code change	Minor code change	Minor code change				
	Test if image received							
End to End test	Test the complete functionality							

Market Analysis

A data driven approach to understanding the cost implications is highly important as decisions are made to take a concept from ideation to roll out. The industry definition of cost-benefit analysis is the *process of comparing the projected or estimated costs and benefits (or opportunities) associated with a project decision to determine whether it makes sense from a business perspective*. The current market landscape has several attempts towards fully autonomous delivery robots .

Here is a tabular comparison across different dimensions, namely types of operation, carrying capacity and the differences compared to PackagePal, the prototype under research.

Company/ Product	Type of Operation	Carrying Capacity	Differences compared to The PackagePal	Appearance
Effidence, PostBOT	Follows a person	330 Lbs	The driver still has to walk and all the robot does is follow the driver to the doorstep. This doesn't help employment rates of the differently - abled drivers go up, but if the PackagePal was there, the driver would be able to stay seated.	
Starship Technologies/ Robovan	Autonomous	20 Lbs	<ul style="list-style-type: none"> - Recipient has to be present for the package to be received and delivered. - only a two mile radius which causes more units needed - With the PackagePal, the recipient doesn't have to be present and since the PackagePal will be in the mail truck itself, there is no radius limitation 	
Australia Post	Autonomous	N/A	<ul style="list-style-type: none"> -Energy inefficient -No charge -Recipient has to be present -Multiple trips to postal service -With PackagePal, the robot does not have to go all the way back to the postal office and if it is a co-bot, it is more energy efficient and the recipient does not have to be present for the package to be dropped off. There is also no additional fee for it to be used. 	
PackagePal	Co-bot	8-10	<ul style="list-style-type: none"> -Energy efficient -no extra charge -Recipient does not have to be present - Does not completely replace the delivery driver, rather, it helps them deliver packages, especially differently-abled and senior driver people. The PackagePal also helps improve employment rates for differently-abled people, senior citizens, and veterans, while other solutions don't. 	

Cost Analysis

The remote controlled PackagePal solution costs ~\$325-350 with the repurposed chassis costing \$200, the PC board and conveyor belt costing \$100-\$125 and the camera costing \$20. Since the PackagePal is remote controlled, it can simply be integrated with last mile delivery trucks with no changes, assuming there is a ramp for the robot to be driven in and out of the truck. Furthermore, the HelpingHandBot has been constructed with LEGO Mindstorms EV3 kit/LEGO Spike Prime kit, which costs \$400. Some modifications to delivery trucks is likely required to allow the HelpingHandBot to be placed on the side of the truck at the elevation that allows for opening and closing of mailboxes. For a more robust solution, a solar battery powered HelpingHandBot can be designed, machined and integrated with sturdy metal/materials for approximately the same cost of the LEGO kit. A slider will also likely be needed that

allows the HelpingHandBot to be pulled closer to the driver to place mail/small packages into the arm of the robot. Although the slider has yet to be designed and tested within USPS mail trucks, from a manufacturing feasibility standpoint, it should be fairly simple as the working prototype is simple in design and development without compromising on a technological and innovative advantage. The prototype has been developed by upcycling the resources at hand, thereby keeping low cost in check.

Alternative Solutions

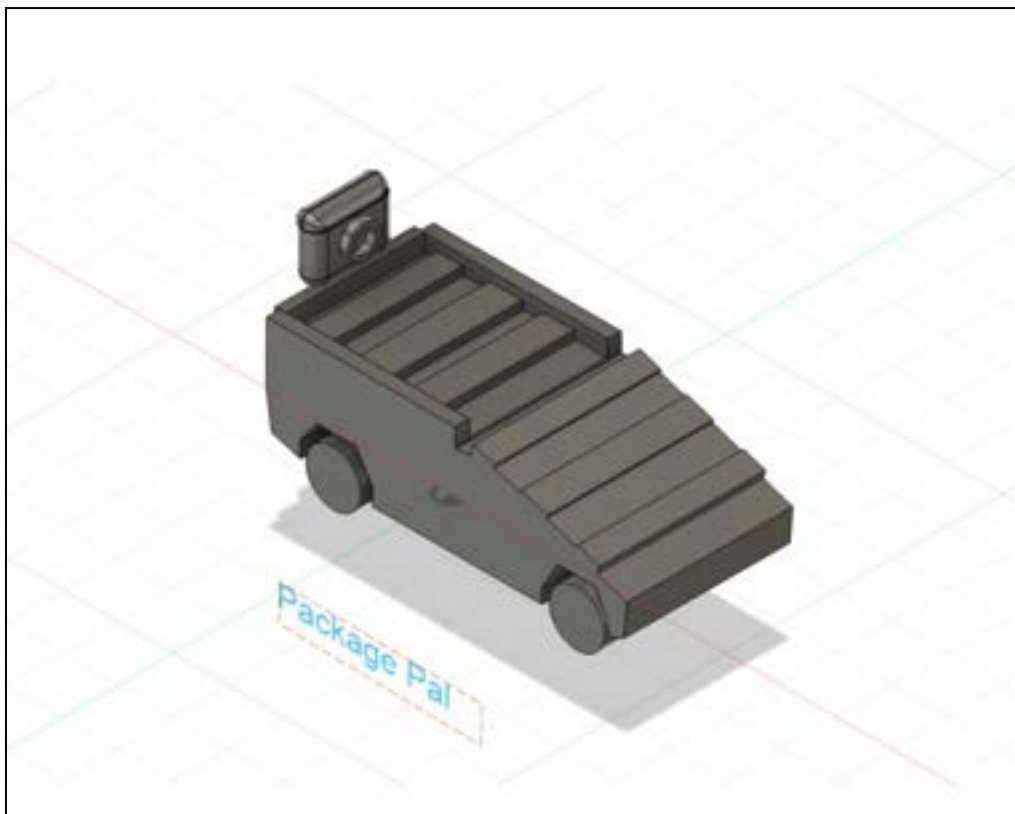
This solution solves the identified problem in a new way by using the concept of “Cobots” - collaborative robots that aid drivers with disability gaining employment as last mile delivery drivers. The HelpingHandBot is a robotic arm that can be mounted on either side of the vehicle, and can help deliver mail / small packages. This is unique especially in the United States because currently mail men or delivery drivers have not been using an automated delivery mechanism especially with no change to mail delivery vehicles currently in place. Initial research has shown that Detroit based “Quadrobot” plans on implementing with the Chinese postal system, requiring custom delivery vehicles. Although this would represent a commercial implementation of the idea, it is expected to be far costlier as custom vehicles are required to autonomously deliver small packages or mail to residential buildings.

In addition, Starship technologies robotic mail delivery is capable of delivering small packages but are restricted to a three mile radius. Furthermore, their partnership with Mercedes Benz (Robovan) not only requires the use of the Benz van but also needs the recipient to be at home at the time of package delivery. In contrast, this solution will

simply drop the package outside the front door, much like Amazon deliveries do today, and do not need residents to be at home at the time of delivery.

Future Plans for Expanding Usability

From a product standpoint , state of the art AI dashcams can be attached to the prototype as used by fleet management companies. This will help provide a GPS tracker (for real time monitoring), clear pictures and snapshots of delivery using the latest AI , in addition to detecting obstacles on the delivery pathway and sending back alerts to both the recipient and the driver.



Based on the feedback from Walmart and Amazon, this solution can be implemented in conjunction with last mile delivery providers or eCommerce vendors. In order to pitch this solution, the intent is to visit the Amazon Last Mile delivery teams, to discuss integration options and a product feasibility assessment including validating the business plan. From an Operational roll out standpoint , meetings with experts from Amazon last mile delivery division Stephan Betz and Romil Mittal indicate that to gauge a problem it's important to consider reliability and quality control. Therefore, to make the design more robust and reliable,the plan is to upgrade the prototype with all terrain wheels (to be able to traverse uneven surfaces), add a waterproof chassis (to deliver through rain) .Initial research shows that there are options available that will not inflate the cost further.

Conclusions and Recommendations

PackagePal, helps by carrying large packages, and delivering them to the door via a unique custom designed 3D printed conveyor belt system. Compared to existing solutions , this solution in combination with existing delivery trucks equipped with helping hand robots, brings in the much needed disability inclusion that will help promote employment opportunities for disabled drivers and innovate in 2-ways, 1/The recipient of the package does not need to be home in order to receive a package, 2/there are significant cost savings by the elimination of the need for retrofitting trucks to use helping hand or delivery Cobots. This prototype provides proof that a compact ,cost effective, eco-friendly tool can be implemented in the last mile delivery sector

specifically to usher inclusion in their workforce and help set people with disabilities for success in their job as last mile delivery drivers.

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Restoration of Degrading Coral Reefs in India

By Aishani Das

Abstract

Due to the increasing global warming, pollution and commercial fishing practices being carried out in the eco-sensitive zones and habitats of corals, there is a reported increase in the degradation of corals in India. This policy paper focuses on examining and analyzing the overall impact of the coral reef ecosystem in protecting the coastal flora and fauna. Further, it also delves into the significant reasons behind coral degradation, current rules, regulations, and policies that aim to conserve the corals in India and suggest policy-based solutions and recommendations that the Government and the other relevant stakeholders may consider implementing to further safeguard coral reefs for future generations.

Keywords

Coral Reefs, Coral Bleaching, Wildlife Protection Act, Coastal Regulation Zone

Introduction and background of the issue

Coral Reefs, also known as the “Rainforests of the Sea”, are more than just colourful underwater charmers. Interestingly, only one percent of the ocean floor is covered by coral reefs, but they still provide a quarter of all aquatic life with a crucial ecosystem (Cho, 2011). According to the United Nations Environment Programme (“UNEP”), it is estimated that 20% to 50% of these reefs have already been destroyed, and another 60% are under severe danger (UN Environment Programme n.d.).

This poses a major threat to the environment and economies of various countries, including India. Around the world, millions of people rely on coral reefs for food, employment, and protection. Further, they reduce the destructive potential of storms, hurricanes, and other cyclones, as well as the energy of tsunamis. The corals contribute to the prevention of coastal erosion by absorbing wave energy. In doing so they protect both the ecosystems, between the reefs and the coastlines (Coral Guardian n.d.).

According to estimates provided by the National Marine Fisheries Service, the commercial value of fisheries derived from coral reefs in the United States is greater than USD \$100 million. Moreover, dive tours, recreational fishing expeditions, hotels, restaurants, and other businesses located close to reef ecosystems also bring in billions of dollars for local economies (National Ocean Service n.d.).

Therefore, the services provided by the coral reefs (both tangible and intangible) are of immense importance and value. Hence it is essential that the public at large, along with their respective Governments, make a collective effort to preserve the coral reefs. Therefore, with this context, this policy paper will further delve into the reasons for the deterioration of coral reefs in India, discuss the policies that the Indian government has put in place to preserve them and analyze new policies and recommendations that may be implemented in the future.

Causes of Coral Degradation

Coral reefs are made up of colonies of small individual corals, called Polyps, that can number in the hundreds to thousands. These marine invertebrates are immobile, meaning they don't move around much, owing to their tough

exoskeletons formed of calcium carbonate. Corals are highly sensitive; hence their decline can be attributed to multiple factors such as:

1. Suffocation of corals due the rapid growth of algae and other creatures caused due to runoff and pollution released from land sources, such as sediments, nutrients, chemicals, pesticides, oil, and debris.
2. Overfishing as well as damaging fishing methods like dynamite and cyanide. Spraying or pouring cyanide onto reefs to stun and capture live fish is also known to harm coral polyps and degrade the reef ecology. In fact, fifteen or more nations have acknowledged that using cyanide in their fisheries, and blast fishing has an impact on more than forty.
3. The practice of collecting live corals for use in aquarium trade and mining of corals for use as construction materials are also major threats.
4. Leftover fishing nets pose a significant threat in high-wave activity zones. When these nets are used in areas of shallow water, living corals can become entangled in them and have their bases torn out. Further, fishing boat anchors can also damage reefs by dragging and breaking coral.
5. Rising sea levels altered storm patterns, and other impacts on marine life are all attributable to the increased levels of greenhouse gases produced by human activities like deforestation and the burning of fossil fuels for heat and energy. Such activities along with the consequent changes contribute to issues like widespread coral bleaching and the increasing devastation caused by storms (National Ocean Service, n.d.).

Notably the phenomenon of “Coral Bleaching” occurs when corals lose their pigmentation. Microscopic algae known as Zooxanthellae provide the coral with their vivid colours. When the temperature of the ocean rises, the coral becomes stressed and expels the algae. Consequently, the coral gradually loses its colour until it looks bleached. High temperatures kill coral because the coral won't allow the algae to return.

Even a two-degree Fahrenheit rise in water temperature is enough to force coral to displace algae. There are a number of potential causes of coral bleaching, including exceptionally low tides, and excessive sunlight.

According to the National Oceanic and Atmospheric Association (NOAA), 75% of the world's tropical coral reefs suffered heat stress high enough to cause bleaching between 2014 and 2017, 30% of the world's reefs succumbed to heat stress and died (World Wildlife Fund n.d.).

Ongoing efforts to protect Coral Reefs in India

The Ministry of Environment, Forest, and Climate Change (“**MoEFCC**”) is India's regulatory organisation that is responsible for the protection of the country's natural resources and the environment. MoEFCC is in charge of implementing a number of regulations and laws that are designed to preserve and protect coral reefs. These reefs are an important component of the country's marine biodiversity and support the livelihoods of many coastal communities.

In India, there are a few laws that exist to safeguard coral reefs, including the Wildlife Protection Act (“**WPA**”) of 1972 and the Environment (Protection) Act of 1986.

However, the only piece of legislation specifically protecting coral reefs in India is the Coastal Regulation Zone (“**CRZ**”) Notification 1991, and coral reef regions fall under the CRZ-1 category. The islands of Andaman, Nicobar, and Lakshadweep are under a unique category called CRZ-4 (Khambete 2021).

The CRZ 1991 notification had several shortcomings such as standardised regulations across the entire length of the Indian coastline, which posed an issue because the region's unique biodiversity, natural resources, demographics, etc were ignored. There was no defined path for getting CRZ approval, hence companies struggled to get permission for activities near coasts. Land-based pollution control measures and regulations were left out. Lastly the CRZ had an adverse impact on traditional coastal population, which included fishermen, slum dwellers, etc.

In order to rectify the existing issues, the 1991 Notification was amended in 2011. While the CRZ Notification 2011 addressed the issues created by the 1991 Notification, its main objectives included preservation and maintenance of coastal areas, safeguarding the economic well-being of fishers and local communities in coastal areas, fostering growth in a sustainable fashion based on scientific principles that account for natural dangers and rising sea levels. However, the MoEFCC continues to face challenges relating to implementation of the CRZ Notification as several stakeholders (including coastal states/ UTs) seek to be exempted from the ambit of the 2011 Notification (Drishti IAS 2020).

The updated Coastal Regulation Zone Notification, 2011, lays out standards for protecting coral reefs and other coastal ecosystems and restricting activities within the coastal zone. The development and growth of industries (like fishing units), tourism activities, building operations, and transferring hazardous material, among others, in the coastal zone are all subject to the notification, which is issued by the MoEFCC under the Environment Protection Act, 1986. Each coastal state in India is required to create a Coastal Zone Management Plan as a result of the announcement.

The CRZ is divided into four categories based on their ecological sensitivity and significance:

1. **CRZ-I:** Includes ecologically delicate areas including mangroves, coral reefs, sand dunes, and sea turtle nesting grounds. The CRZ-I zones are the most ecologically fragile and are afforded the greatest level of protection. In these areas, no new construction or development activities are permitted, with the exception of certain activities essential to the survival of the local communities.
2. **CRZ-II:** Includes urban regions with established infrastructure. These zones are urban areas with established infrastructure. Certain construction activities are permitted in these zones, pending approval from the appropriate authorities.
3. **CRZ-III:** Include non-urban and rural areas. Certain construction activities are permitted in these zones, pending approval from the appropriate authorities (PMF IAS 2016).
4. **CRZ-IV:** Include the marine areas within 12 nautical miles of the coast

Marine Protected Areas

Marine Protected Areas (“MPA”) in India are the areas defined under the International Union for Conservation of Nature (“IUCN”) Guidelines. The Andaman and Nicobar Islands, the Gulf of Munnar in Tamil Nadu, Thane Creek in Maharashtra, and Sundarbans in West Bengal, are examples of a few Indian marine protected areas.

MPA is a specific section of the ocean or coast where human interference is limited and restricted to a greater extent than in neighbouring waters. National, regional, state, and local governments all provide additional measures in these areas to protect marine life. Coral reefs fall under category 1 of the MPA (Clear IAS 2023).

India has 36 MPAs, 5 of which are designated specifically for the protection of coral reefs. These include the Great Nicobar Biosphere Reserve and the Rani Jhansi Marine National Park in Ritchie’s archipelago in the Andamans, as well as the Gulf of Mannar Biosphere Reserve and the Gulf of Kutch Marine National Park.

There are challenges to ensuring the safety of MPA due to the lack of strict enforcement of the available laws and regulation. Further, the laws are loosely formulated and difficult to effectively implement. The WPA does not include coral reefs that lie outside of marine protected areas, due to which taking legal action against violators outside the park is challenging (Khambete 2021). Effective management of MPAs requires substantial financial resources to pay for enforcement, monitoring, and research as well. In addition, there can be conflicts with the local communities

as it can make it difficult for them to continue fishing and other coastal activities (Clear IAS 2023).

The Indian Coral Reef Monitoring Network (“**ICMRN**”) was recently established by the National Committee on Mangroves and Coral Reefs under the umbrella of the MOEFCC.

Alternate Solutions

MPA’s are important to safeguard our native flora and fauna as amongst other benefits, it is a significant source of revenue for the local governments and associated authorities, due to the possible marketing activities and tourism in these regions because of the high levels of biodiversity found there. MPAs can also mitigate the effects of global warming. However, all these protection policies focus more on human intervention than climate change. Coral reefs in India need immediate action to reduce coral stresses and increased efforts to reintroduce species through artificial reef restoration.

Micro fragmentation: Corals are unable to recover quicker than the rate at which they are destroyed due to their naturally slow growth rate. Expert coral reef scientist Dr. David Vaughan of Florida's Mote Marine Laboratory has developed a ground-breaking method that can accelerate the growth of threatened corals. This method is called Microfragmentation (Baker 2019). Using a special saw, the corals are cut into pieces with one to five polyps. This promotes the growth of coral tissue, which speeds up the process of creating clones by a factor of 25 to 50. The pieces are stored in shallow water tanks maintained at 22-26 degrees Celsius, where debris and algae are frequently removed. Instead of battling for resources, clone pieces merge to produce larger colonies. After 4–12 months, the corals are ready to be planted in the ocean (Wilson 2018). Along with Florida Keys microfragmentation is being used in various other reefs, including those in the Caribbean and Indi-Pacific (Page, Muller and Vaughan, 2018).

Policy Recommendations

The government is monitoring activity and protecting regions from tourists, fisherman, and builders through the various CRZ notifications and MPAs. However, these policies need to include stricter punishments in order to deter any further violations and need to be carried out in a more effective manner. Further, existing security measures can be enhanced through increasing revenue spent on coast guards, security cameras, and other such measures, including educating the local residents. The government should also increase awareness not only in coastal areas but also in other parts of the country, starting with schools. This could help gather volunteers and donations.

In addition to other strategies for coral reef protection, the concerned authorities may consider formulating and implementing stricter legislations, that would assist in the cause of preservation and regeneration of corals. Because of climate change, it is anticipated that both the temperature of saltwater and its acidity will continue to rise over the course of the next century. Hence it is essential to accelerate their growth while also ensuring that the amount of human interference and damage that occurs is maintained to a minimum. As mentioned in the alternative solutions above the Indian government should provide more incentive to existing research labs to carry out microfragmentation, as well as create a campaign advocated to implementing microfragmentation of coral reefs in the Indian ocean.

Conclusion

Coral reefs worldwide, including those in India, are confronted with substantial threats stemming from both climate change and human activities. This issue holds significant importance due to the myriad of benefits that coral reefs offer. They serve as vital natural barriers, safeguarding coastlines from destructive storms, possess economic value, hold potential for medicinal breakthroughs, and provide a crucial habitat for numerous marine species.

In response to these challenges, the Indian government has implemented various policies and laws, such as the Coastal Regulation Zone notifications, and established Marine Protected Areas. Over the years, the CRZ notification

has undergone various improvements and enhancements, leading to increased efficiency. However, despite these efforts, the decline of coral reefs remains a pressing concern.

Therefore, it becomes imperative to educate a wider segment of the population about the grave dangers we face and allocate financial resources towards establishing research laboratories and programs dedicated to the study of coral reefs and climate change. This investment will facilitate the exploration of potential solutions to this critical issue.

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How has the dramaturgical process approached adapting different musicals?

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Abstract - This paper delves into the role of dramaturgy in musical theater production and explores the intentions behind transforming source material into the form of musical theatre. The study includes close reading, and literature review methods on the staging of adapted musicals, in the analysis of two case studies: *Hamilton* and *Into the Woods*. In examining the case studies, the writer's interest lies in understanding the approaches and processes in musical theater. One case study focuses on the adaptation of Alexander Hamilton's life story and the history of the founding of the United States, while the other revolves around the transformation of fairy tales from the Brothers Grimm. The paper concludes by discussing the nuances of adaptation in musical theater, examining how and why ideas are conveyed differently between the source material and the adapted musical through the dramaturgical adaptation process, and argues how the dramaturgical process in *Hamilton* and *Into the Woods* developed each musical's narrative arc.

Index Terms – Adaptation, Dramaturgy, *Hamilton* the musical, *Into the Woods* the musical, Musical Theater

I. Introduction

With the increasing prominence of adapted musical theater, dramaturgical scholars have begun to consider the role that dramaturgical practices play in the phase from primary source to stage. The paper will take this as an entry point, using the methods of close reading and literature review in two case studies (*Hamilton* and *Into the Woods*) to explore and analyze the research

question: How has the dramaturgical process approached adapting different musicals? It will summarize the stage presentation and the impact of the adaptation process and results.

The dramaturgical process used in the musical theater production that I focus on in this paper is what allows for the source materials to have an expanded narrative arc. In this paper, I articulate how the dramaturgical process of adapting source material emphasizes an expanded pathway of storytelling. By investigating the nuance relationships, I argue that the expanded narrative arc is what allows source material to be differently understood by audiences in the form of musical theater.

The word narrative arc usually refers to a structured pattern of storytelling, however, in musical adaptations, the strategy of expanding the arc of how stories were being told could further develop and build alternative messages from the source material, and provide audiences with enriched story content on stage. This adaptation could be considered as a dramaturgical process of how dramaturgs approached adapting material sources onto the musical stage. To be specific, the building of a musical's narrative arc based on original materials has often added nuance to a musical's expressive qualities. The nuanced relationship between the adapted narrative arc is generated through the dramaturgical process, allowing the audience to view this existing story from perspectives and entry points that were different than before. When referring back to the two case studies, ...we can identify how the dramaturgical process adds complexity to themes and key ideas.

In this paper, my focus is on two musical case studies, *Hamilton* and *Into the Woods*, to demonstrate how dramaturgy can expand the narrative arc. In *Hamilton*, I show how the use of hip-hop style music contributes to the development of the characters Aaron Burr Jr. and Alexander Hamilton. In *Into the Woods*, I articulate that the same story/production allows for more complicated and modernization.

What is Dramaturgy and Dramaturg?

The word dramaturgy originally came from the Ancient Greece term "*Dramaturgia*" (δραματοουργία), a combination of "drama" and "urgia", which simply translates to "making drama". *Dramaturgia* was first used to describe the activities of playwrights and producers of theatrical events. As time progressed and drama gained global popularity, *Dramaturgia* then became the name of historians and theorists of drama and performance. It wasn't until modern

times that "dramaturgy" was formally acknowledged as a research field focusing on artistic expression, encompassing the study and practice of dramatic composition, structure, and performance. While dramaturgy transcends mere occupation to embody a form of theatrical creativity, it remains challenging to define concisely. The dramaturgical process is a collaborative endeavor where most people in the crew are involved: The dramaturgical approach might occur when an actor is researching and reflecting on his or her role to better perform on stage, or when a stage manager documents a rehearsal, as well as when a scenic designer tries to sketch a stage design. The approaches can be consciously or unconsciously engaged in the creative process of researching and imagining – consider how an actor can deliver a compelling stage performance without understanding the play's significance or the reasons behind its creation or adaptation. For example, if an actor is preparing to perform a musical version of *Oedipus*, but he is unaware of the character's myths, legends, and related background stories, then his character on stage is likely to be not developed enough, and without soul.

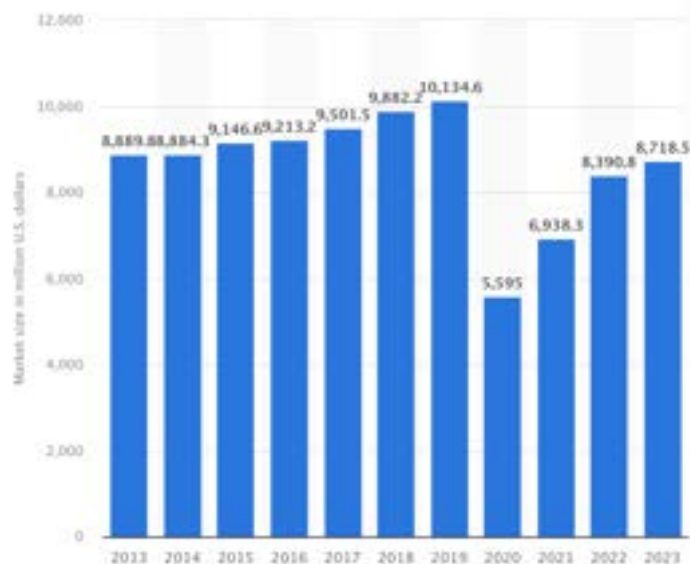
Similarly, there is no absolute definition of the role of a dramaturg; in musical theater, there might be a dedicated dramaturg, or the director/playwright could fulfill that role. But what is undeniable is that the technique of dramaturgy is crucial for creating a compelling play: it shapes what's on stage and connects the play's world with the real one. The renowned dramaturg Anne. M. Hamilton described dramaturgy as "a process integral to the origination, development, production, and reception of plays and theatrical performances." (Walter Byongsok Chon and Hamilton 2022)

Interpreted from a practical point of view, dramaturgy has quite a wide range of applications, "the dynamic and self-reforming nature of theater production means there can be no uniform way to practice dramaturgy" (Chemers 2022). Not only is everyone participating in the production aware of the importance and practice of dramaturgy to some extent, but the role of dramaturgy can exist simultaneously for directors, designers, and playwrights. Moreover, Berklee College of Music describes the dramaturg's role as a "Literary Manager", where they serve as a resource for directors, playwrights, and actors. A dramaturg's job in a crew is to manifest ideas onto stage, to ensure the accuracy of a production. ("Dramaturg" 2024) The dramaturgical process is one of the great mediums from source material to stage, and the dramaturgs in the cast work throughout the entire production – they also serve as Literary Managers and even Education Directors – Professor Chemers from the University of California Santa Cruz describes the dramaturg's job as "the director's second set of eyes," always looking at the musical from multiple perspectives. (Chemers 2022) The question at hand is, how do dramaturgical process and practice utilize their research, interpretation, and collaboration skills to adapt various materials into a musical production? It is necessarily a complex and

multifaceted process that requires careful consideration of the trade-offs between material and creative decision-making.

Why is dramaturgy adaptation needed on stage?

In the present-day world, live performing arts are fast becoming a popular mainstream culture. Broadway, the world's most renowned industry, serves as a prime example, with its market size consistently growing in recent years. Despite the setbacks caused by the COVID-19 Pandemic starting in 2020, which led to cancellations and closures of many performance venues,



Market size of the live performance theater industry in the US, from 2013 to 2022, with a forecast for 2023

the market size of Broadway has remarkably rebounded upon reopening, almost reaching pre-pandemic levels. As of 2022, the industry forecast market size reached 8.7185 billion US dollars after one year. The frenzied pursuit of live performance theaters is quickly bringing ticket sales back to where they should be this decade. (“Statista” 2023)

With the popularization of musicals, more practices and improvements related to drama in theater are also being explored. Dramaturgy is one of the most essential jobs in a productive musical theater, while not necessarily a designated role within the production crew. Dramaturgy is a crucial aspect approached by most involved, particularly playwrights and directors. The importance of drama on stage stems from the need to create eye-catching and successful theatrical works. When adapting different materials into musicals, in common cases, the practical

research and analysis of dramaturgy are related to the coherence and effectiveness of the adaptation.

Dramaturgy is necessary to inject “new life” into existing materials. When a story or concept that already exists in a certain form is adapted into a musical, it undergoes a transformation - in other words, translating the narrative into dramatic language. This process requires careful consideration of how to present the story visually, audibly, and emotionally, while in some cases regarding different types of source material, it needs to take into consideration remaining faithful to the essence of the original material and convey emotions at the same time. In the process of dramaturgical approach, people often use dramatic techniques such as analyzing structure, themes, and character curves. Theater can help shape adapted works and attract audiences in live performance environments. Unlike some media that contain limitations regarding accessibility, (for example, short videos or movies), musical theater has its own set of limitations and possibilities: for example, limited space and limited performance methods require thoughtful adaptation techniques. Understanding these nuances is crucial in guiding creative teams to optimize the theatrical experience. In the research process of creating a musical theater piece, it is not only necessary to consider the script's text but also to combine factors such as stage, choreography, vocal arrangement, and music integration to enhance the influence of the story on the stage as a presentation method.

According to data analyzed in 2014, in the past 30 years, 82% of the new musicals on Broadway were adaptations, while only 18% were entirely original. Adaptations have consistently enjoyed longer runs, averaging 644 performances, nearly twice the original musicals' average of 331 performances. This trend underscores the enduring popularity and prevalence of adapted musicals in today's theater market. (Davenport, 2014) This data cannot be separated from the understanding, research, and presentation of source material by countless dramaturgs; At the same time, the result is somehow revealing from the audience's viewing preferences. Based on the quantitative result of 82% of musicals being adaptations while it doubles the performances of original musicals, hence we can conclude that the audience is willing to watch performances by adaptation, that they have an "understanding and a sense of familiarity" with. Adaptations serve as a bridge between original works and audience comprehension, offering interpretation and contextualization layers that deepen the audience's connection with the narrative, it provides a layer of interpretation and contextualization, allowing the audience to connect more deeply with the story. By delving into the historical, cultural, and thematic elements of the original materials, drama can help clarify its significance and relevance to contemporary audiences. This understanding is crucial for creating a work that resonates with and attracts the audience intellectually and emotionally.

The existence of source-material-adapted musical theater

While this paper appears to distinguish between "adapted musicals" and "original musicals," it is interesting to note that there isn't a strict dichotomy between the two (Chemers 2022). Essentially, every new stage production is rooted in some form of source material adaptation, due to the reason that nothing was created based on nothing, hence, the practice of dramaturgy somehow exists everywhere – to be explicit, the characteristic, position, and personality of the characters in an original musical play all contain social basis to some extent. Besides, the style, keys, and many of the songs in original musicals are most likely to be music forms that already exist. Audiences will be surprised to find that most of the world's most famous musicals have been adapted from some other original source material. For example, the “four big musicals” in the East: Miss Saigon; Cats; Les Misérables; and The Phantom of the Opera. Each of these musicals was adapted from diverse source materials, including Puccini's opera "Madama Butterfly," T.S. Eliot's poems, Victor Hugo's novel of the same name, and Gaston Leroux's novel, respectively. It seems that even these four masterpieces fit into the search for "adapted musicals", therefore, it once again illustrates the importance and popularity of source material adapted musicals. (London. cn, 2024)



Stills from Musical *Roméo et Juliette*, wedding scene, 2001.
Anne Mano as Death

In many cases, the secondary creation or edition of a musical's adaptation is intentional to serve a certain theme or title. An example can be seen in the famous French musical *Romeo and Juliet* – which was adapted from playwright William Shakespeare's play. In the process of dramaturgical adaptation, the character of 'Death' was added to the musical. Death is a character rich in symbolism, embodying the doomed destiny of Romeo and Juliet. Death quickly

became one of the most significant roles within the musical. This example highlights the critical role of dramaturg in the adaptation process. Dramaturgs bring their expertise in playwriting, interpretation, and contextual understanding to bear in shaping the adaptation. Not only do they build elements of the material from existing sources (in this case, Shakespeare's original play and Shakespeare's own expression of the main ideas of the story of this pair of Verona lovers), but

they also come up with innovative ideas that will highlight or diminish some of the concepts or main ideas in the play (the creation of the character Death), this gives the audience a more meaningful characterization and a more renewed experience on the musical theater stage. In the case of the musical production of *Romeo and Juliet*, the character of Death is presented on stage as a first-person dancer, providing a new and unique perspective while ensuring that the adaptation retains the essence of the original work. The role of Death can be played by either a male or female actor, demonstrating the inclusivity and uniqueness of the character. The role is one of the highlights of the *Romeo and Juliet* musical and is popular worldwide, emphasizing its impact and appeal to culturally diverse audiences. (Paravano 2024) The development of the character's death therefore served to the expansion of *Romeo and Juliet*'s storytelling, the nuance of adaptation of the character enriches the key ideas about love, death, and fate, while it also provides the audience with new experiences on the story when watching the musical production.

II. Case Studies

Dramaturgically adapted musical case studies

Case Study A: *Hamilton the Musical*

As one of the most sought-after new Broadway musicals of the 2010s, *Hamilton the Musical* not only breaks the music stereotype of musical singing (e.g. Opera, bel canto) by centering the form of hip-hop but also resonates with audiences of all ages because of its use of the founding of the United States as its plot. The musical gathered top composer Lin-Manuel Miranda and top actors Renee Elise Goldsberry and Lelie Odom Jr. and was awarded eleven Tony Awards and the Pulitzer. (Wallenfeldt 2023)

Hamilton the Musical is a historical source-adapted musical – its original source was the actual history of the founding of the United States. For historical accuracy, dramaturgs need to focus on the multifaceted nature of history



Hamilton still, historical figures are performed by musical actors on stage. (Mandell 2015)

and its authenticity. It is therefore necessary to consult a large number of books and historical records from a variety of perspectives, as well as obtain first-hand information through interviews with researchers and experts in specific fields.

In the dramaturgical process of adapting *Hamilton*, I argue that the use of hip-hop style music added nuance and developed characters more thoroughly by focusing on their language, history, and music choice in the musical, thereby expanding the narrative arc of the musical.

Analysis of how dramaturg adapted #45 *The World Was Wide Enough*: The Burr-Hamilton Duel

The World Was Wide Enough is an important song in *Hamilton the Musical*, announcing one of the most important duels in the show, as well as the eventual end of Hamilton, the protagonist, who is shot in the duel and dies a heroic death. Many of the lyrics in the song are rap, which was not a common music style in the form of music. Rap music has a characteristic containing unique rhythm and the ability to output more information in a limited amount of time compared to other forms of music. In #45, the lyrics here are narratives of events that happened in history and tell the chronological and spatial development of the duel. Dramaturg uses such

BURR

There are ten things you need to know.

COMPANY

Number one!

BURR

We rowed across the Hudson at dawn.

My friend, William P. Van Ness signed on as my—

BURR AND COMPANY

Number two!

BURR

Hamilton arrived with his crew:

Nathaniel Pendleton and a doctor that he knew.

COMPANY

Number three!

BURR

I watched Hamilton examine the terrain.

I wish I could tell you what was happ'ning in his brain.

This man has poisoned my political pursuits!

rap form to state the process of time and details of the occurrence of time. This greatly increases the content that can be stated, and at the same time brings seriousness and excitement, due to its fast-paced expression and dynamic musical emotions.

In the song, Burr first mentions that "there are ten things you need to know," the ensembles follow up by listing them in the lyrics. Looking back at the official historical record, the audience will realize that Burr is largely a reliable narrator in the musical. This is evident from the meticulous details of his involvement in the duel, such as the location and timing ("we rowed across the Hudson at dawn/My friends, William P. Van Ness signed on as my"), as well as Burr's introspective musings

following Hamilton's demise ("When Alexander aimed at the sky/He may have been the first one

to die/...I survived but I paid for it") These instances align with documented history, wherein Burr indeed arrived first at the duel site in 1804, donning a bulletproof jacket and setting sail from Hudson's dock in the early morning hours. At the end of the duel, Hamilton survived 31 hours in the hospital after being shot in the stomach and eventually died. Burr said he paid the price for this decision - he was indicted for murder and was never able to regain his political reputation for the rest of his life. In the historical record, Burr approached Hamilton after he had been shot with a look of complexity and regret on his face.

Hamilton's reflections during the duel and Burr's afterward are equally present in the song's lyrics. The dramaturgical design here uses flashbacks to bring back the "rewind" format, allowing Hamilton to meet his most important companions and loved ones before he dies, and to express his love and determination for them. With such dramaturgical adaptations in the script, the heartfelt thoughts of a historical figure who once existed are brought to the stage. Although Hamilton says nothing about his own greatness, the adapted script still manages to narrate his greatness in a special way in a first-person monologue combined with the presence of other characterizations. As for Burr, his last few verses are considered one of the most moving parts of the show for the audience. Unlike the fast-paced rap format that preceded it, here the tunes become soothing, and the lyrics sincere. The slow ending leaves room for the audience to think and feel Burr's regret and grief. The dramaturgical adaptation of the characters in this musical is not absolute, and history isn't black and white either. Similar to popular kids' cartoons, there will always be positives and negatives, but that isn't the way history should be viewed, and each character's existence and beliefs are complex. Although formally a villainous presence, Burr's entanglements, struggles, and regrets are all present in his lyrics, accompanied by quiet tunes, and the multifaceted nature of the individual is thus lyrically expressed onstage. The nuance and

complexity of characters is also something that builds on the musical's narrative arc.

BURR

Were both at his side when he died.
Death doesn't discriminate
between the sinners and the saints,
it takes and it takes and it takes.

In every picture it paints,
it paints me with all my mistakes.
When Alexander aimed
at the sky,
he may have been the first one to die,
but I'm the one who paid for it.

I survived, but I paid for it.

Now I'm the villain in your history.
I was too young and blind to see...
I should've known.
I should've known
the world was wide enough for both Hamilton and me.
The world was wide enough for both Hamilton and me.

Both Hamilton's and Burr's portrayals are thought-provoking, and the presentation of the song on stage combines a multi-person perspective, allowing the audience to understand the richness of the characters at the same time, and making a "one-sided musical" more solid, which, despite the limitations of the stage and the length of the show, it should be a multi-dimensional work to enrich character images. This serves to enhance historical authenticity and evoke the

emotions of the characters, a significant achievement from various perspectives. (“Hamilton Lyrics,” n.d.)

The hip-hop features in Hamilton

Although it is a modern musical, *Hamilton* was one of the earliest to have hip-hop and rap throughout the script. The dramaturg’s decision to use such a musical form here also has to do with the context. The structure of this choice serves a dual purpose: firstly, to sculpt the character, and secondly, to narrate the life of Hamilton, the central figure, compacted into a brief timeframe. Firstly, the fast hip-hop song style and rap greatly highlight Hamilton's confident and knowledgeable character traits. This feature is not only applicable to the character of Hamilton, but other characters with similar personal traits: Angelica Skyler, Burr, and Lafayette also have rap scenes. Secondly, this musical has a significantly longer page length than most other shows on Broadway due to the large time span. Condensing a fifty-year story is a great test of the analysis and application of dramaturgy. Hip-hop and rap forms can cleverly accelerate the storyline, while other musical modes in this play can be incorporated to highlight key points of storytelling, for example, when the plot is in a sorrowful state, the musical song is more smoothing and aria-like, while emotional scenes are more often in the form of rap. (Baker 2020)

Through the analysis, we can see that *Hamilton* the musical expresses the narrative arc adapted from history from an understandable perspective. By expanding the narrative arc and utilizing dramaturgy processes, musicals can develop complex alternative information and provide rich story content on stage. This is particularly evident in the song *The World Was Wide Enough* through Burr's narrative and lyrical expression. The audience's understanding of history has been influenced by this artistic expression technique, and they have understood the history under such expression from a novel perspective. In addition, hip-hop and rap forms help accelerate the storyline, while other music modes are also incorporated to emphasize the key ideas of the story. In the example, the use of hip-hop rap as a musical form not only highlights Hamilton's confident and knowledgeable personality traits but also allows for a concise depiction of the lives of historical figures in a short period of time, driving plot development. This method and nuance-changing expressions therefore expand the narrative arc, enhance the authenticity of the historical background through artistic presentation techniques, establish the emotions of the characters in the nuance choice of character shaping, and thus make the character images on stage more three-dimensional and meticulous, contributing to the arc of storytelling.

Case Study B: *Into the Woods*

Into the Woods the Musical was famously known for its music created by Stephen Sondheim, an irreplaceable composer of legendary 20th-century musicals. Besides, its plot is also very intriguing – the story of *Into the Woods* was collaged based on several Brothers Grimm magic tales, including Cinderella, Jack and the Beanstalk, Little Red Cap, Rapunzel, The Baker and his Wife, Snow White, and Sleeping Beauty. All seven stories originated by the Brothers Grimm might seem to have different backgrounds and values, but they do share the common characteristics in story structure frameworks of fairy tales: First, the core of the stories are short and not detailed, which allows the space for collage and interpretation; second, the tales happened in “Once upon a time”, indicating that they are timeless and spaceless, which also provide the dramaturg with freedom on conceptualizing and confirming a suitable and meaningful time and space for adaptation; Third, most characters in the plot, are often called archetypal characters, (e.g. worried mother, cunning witch, playful prince, beautiful princess, naughty little girl) which means the characters do have a fixed set of character traits in the conventional understanding of the audience. The audience's perception of these characters has existed for a long time, and dramaturgs can not only assist with character design but also provide secondary adaptations to give the characters new insights into meaning. Identifying similarities and commonalities allows the musical to adapt further and combine the stories into one worldview. Using a piece of wood as an imagery backdrop to set and connect the fates of these characters, this musical cleverly threads these stories together, making it a musical with novelty and familiarity that can appeal to all ages. (“UPSTAGE GUIDE” n.d.) The nuance difference of “collaging” added to existing stories and character backgrounds contributes to the adaptation of *Into the Woods*, and allows space for the expansion of the narrative arc.

Adapting fairy tale into real life

In 1987, when the musical *Into the Woods* officially premiered on Broadway, it quickly became a remarkable musical because its content was truly uncommon – *Into the Woods* cleverly utilized familiar child characters to explore modern relational themes, especially the relationship between parents and children, giving audiences a new



“*Into the Woods* is a cautionary Fairy Tale for the ‘80s”
The still includes Little Red, Jack, Cinderella etc., from fairy tale. (Sheryl 2022)

understanding of the story of the adapted creation, Therefore, it quickly gained recognition from critics and audiences. As the playwright and dramaturg, James Lapine delved into the consequences of human excessive desires, morality, and behavior. The complexity of the musical "Into the Woods" lies in its complex plot and well-developed characters, which requires these traits to be the highlight of the development. The method of creating an ensemble involves seamlessly integrating various materials, ensuring that the journey and overall narrative of each character are given equal attention. By blending these vastly different fairy tales, Lapine and Sondheim created a captivating musical. The clever adaptation of the original materials into a unified story showcases the drama's ability to coordinate different elements and promotes a seamless transition from the page to the stage. ("MUSIC THEATRE INTERNATIONAL," n.d.)

Adaptation to the dark magic tale

Those of the audience who have seen the musical or the movie will know that what makes *Into the Woods* a sought-after novelty musical is not just the fact that it's a collection of Grimm's fairy tales, but also the fact that the plot takes an unexpected turn from "happy ever after" in the Act 1 to the world of "dark fairy tales" in the Act 2. It's also because it takes an unexpected turn from "happy ever after" in Act 1 of the show to the world of "dark fairy tales" in Act 2. "Subversion" is the keyword here. The design of the musical characters no longer conforms to the previous archetypal characters, and the plot is no longer geared toward the usual happy ending. In the musical, the setting can be confusing to some audiences because the use of woods as where the story unfolds was not a common purpose regarding fairytale stories. Jack's curiosity is rewarded with the death of his mother, the prince is no longer loyal to his princess because of his dissatisfaction and the baker's wife has an affair with the royal family although she knows such behavior obeys her husband ... All the temptations seem to be unbelievable to happen on fairytale characters, and in the fairytale world. However, they are realistic enough to subvert the audience's perception of the "fairy tale world will always usher in a happy ending". The difference between how people originally view fairytale plot to what actually happened on stage demonstrates how enlarging the narrative arc could be like, and how it brings possibilities to adaptations.

Sondheim's music and lyrics choice

The story of *Into the Woods* delivers multiple key ideas and features that are more realistic than the original fairy tales – about wishes and desires, about truth and lies, about individual and community, and so on. The adapted fairy tales does contain morals regarding the power of wishes and desires and their consequences, but the level of intensity as well as the form of communication have somehow changed. The decisions made in creating music of *Into the Woods* follow Sondheim's idea that "content dictates form", where he suggested the musical

form should follow its content and needs, therefore much more adaptation happened within the music design.

People have commented that the chords of this play are bizarre and disconnected, and this evaluation runs through the entire play. (Buchler) And this is exactly the dramaturgical adaptation that Sondheim made in music: Sondheim believed that the music in musicals served the plot. The accompaniment of the work consists of staccato chords, which are usually emphasized with slight alternative chords (Sondheim 1988) [CD]. From an adaptation perspective, not everything needs to be perfect or pleasant to listen to. Strange musical chords are necessary to further highlight the musical's dissonant content. (Musical Theatre International)

Another special feature is that this nearly three-hour play starts and ends with the same "I wish" lyrics. Sondheim's design here did not follow the fairy tale itself but strengthened the theme conveyed by the musical about the impact of desire on people. He highlighted the common character traits through the "I wish" in each character's mouth and the last sentence before the closing, indirectly implying the importance of wishes and the impact it will have on them in the play, and established unity through each musical piece.

In summary, the plot of *Into the Woods* was based on changes in Grimm's fairy tales, the fact that it combined stories together and created a theme of "cautionary tale" that fits the modern audience client is an insightful creation that demonstrates how dramaturgical process adapted different materials into musicals. The nuance between the original and musical contributes to changes to expand the narrative arc of the fairy tale story, from fairy tales to cautionary tales. Also, by carefully aligning narrative elements with Sondheim's lyrical ability, the dramaturgical process transformed traditional fairy tales into contemporary explorations of broadly accessible themes. Their approach emphasizes the importance of maintaining the integrity of raw materials while creating an engaging and cohesive musical theater experience.

The adaptation of *Into the Woods* reflects the effectiveness of expanding the narrative arc of the original material, especially through a skillful collage of various fairy tales of the Grimm brothers. By combining stories such as Cinderella, Jack and Beanstalk, Little Red Riding Hood, and others, the musical creates a rich and interconnected narrative tapestry. This method is new and unprecedented, providing the audience with an updated perspective to familiarize themselves with the story and explore modern relational themes on top of it. The complex plot, well-developed characters, and seamless integration of these different materials demonstrate the screenwriter's ability to create a unified and captivating story. In addition, the unexpected transition from the happy ending in the first act to the cruel reality in the second act increases the

depth and complexity of the narrative, challenges traditional expectations, and explores human experiences in detail. Through the collage of fairy tales and the expansion of narrative arcs, *Into the Woods* showcases the transformative power of dramaturgy in creating a more realistic story core.

III. Results

In this paper, my argument is that expanding the narrative arc of the original material nuance experience in the adapted musical, as the resulting nuance can explore complex themes and create a novel theatrical experience. In my paper, I have provided evidence to support this argument through the analysis of the case studies of *Hamilton* and *Into the Woods*. Taking *Hamilton* as an example, the adapted works expand the narrative arc of these historical events by incorporating contemporary themes, adopting a diverse cast, and utilizing various music styles. By interpreting historical backgrounds and traditional biographical methods through an artistic approach, this musical delves into the personal growth of characters and the developmental changes between them. This expanded narrative arc allows for a deeper exploration of these themes, arouses audience interest, and triggers important dialogues about history and its relevance in today's world. *Hamilton's* case study illustrates how dramaturgical adaptation can transform historical source material into a musical that is suitable for all ages, and enhance its social significance. Similarly, the adaptation of *Into the Woods* smartly pieced together various fairy tales of the Grimm brothers and incorporated them into modern relational themes, expanding the narrative scope. This expansion allows for a more detailed exploration of human desires, morals, and behaviors and draws conclusions that are more suitable for contemporary society. This musical subverts traditional fairy tale expectations and introduces a darker turning point in the second act, delving into the complexity of the human experience. The musical selection in *Into the Woods* also assists in better presenting its key ideas.

Whether it's *Hamilton* or *Into the Woods*, these adaptations go beyond the limitations of the original material, creating more possibilities and allowing for the exploration of complex themes and the creation of alternative information. By expanding the narrative arc, these musicals present content on stage that differs from the source material but is more novel and suitable for the musical form, reflecting the transformative power of adaptation in the field of musicals.

The musical choice of hip-hop, as mentioned in the *Hamilton* case study, has brought up a more historically nuanced and complex character development. The historical background of the musical *Hamilton* is grand, the overall rhythm of expression is fast, and the characters'

emotions are full. Such artistic expression on stage is a condensed portrayal of history. In addition to rap, musical artistic elements serve to express the images of these characters in dialogue and monologue during the play. Hamilton makes the mistake of infidelity when he lost himself in the gentle voice of Maria Reynolds, while Burr switches from intense to sorrowful after the duel, stating that he was the "villain in your story.". Small musical choices play a decisive role in the expression of character comprehensiveness and complexity, enriching the shaping of characters. Into the Woods' "collaging" combination of collaging the fairy tale story pieces into a realistic and brutal plot has also led to a fresh way of viewing the tale's morals and messages. Here, the extended arc is a so-called patchwork of Grimm's fairy tales, which neutralizes and updates the message conveyed by this musical and expands the possibilities in plot and ideas in theme.

Although adapting an existing material is a re-creation or update on the original background, it also elaborates on the original source from an artistic perspective, which usually means injecting more theatricality into it or even enriching or transforming its morals, features, and ideas from the perspective of musical themes. Adaptation may gain new insights or even deviate from the original intention in a specific social and historical context, all of which rely on the intention of the dramatic process. Compared to individual analysis, the dramatic adaptation uses multiple perspectives to examine the work and presents it in a new form, which can provide more nuanced perspectives, such as the development of each character in Hamilton following historical logic and the transition from a "happy ever after" ending to a more realistic ending in Into the Woods. These more nuanced narrative arcs introduce the keyword of accessibility into discussions of musical adaptation and dramaturgy. By accessibility, I refer to adapting musicals containing certain ornamental qualities so that audiences worldwide can easily access the practice and emotion. The sense of accessibility allows the audience to gain interest and build a connection with the adapted musical, focusing on its practice and emotion. For example, as mentioned in the above research, the biggest triggers that appeal to and that allow the musical to be more accessible to audiences. In *Hamilton*, the complexity of character development has added nuance to stage characters, in addition to expanding the expression of character as a historical figure; in *Into the Woods*, the complexity of an expanded narrative arc rather than a structured fairy tale also changes the audience's ability to access and enjoy the development of both character and plot.

Dramaturgical approaches to adapted musicals shift the narrative arc and expand the storyline, therefore accommodating expanded complexity, and therefore could accommodate wider and deeper adaptations in various possibilities. Just as the serious and recorded history of the founding of the United States can be sung through rap, fairy tales that originally were the

symbols of harmony and happiness are now ending with chaos and death for children. Dramaturgs can approach their adaptations of musicals from a broad perspective. On the level of simplicity and ease of understanding, the extended narrative arc, due to its interpretive nature, is very helpful for exploring theatrical practice and subsequent production. At the same time, the added differences and complexity in the adaptation of this form also contribute to the audience's multi-dimensional understanding and interpretation.

IV. Discussion

In the current development of the industry of musical theater, the adaptation approach regarding creating nuanced changes and expanding narrative arcs to enhance complexity and profundity has been recognized, applied, and improved. The paper results indicate that my research and analysis results support the continuous development and feasibility of this theory and method.

This research topic provides insights as exploring a relatively novel field, thus my work adds critical analysis. Many of the materials I referred to in the paper need to be carefully interpreted and discussed to determine whether they are relevant to the content. The contributions of my work become more critical in the field because there are relatively fewer research papers related to the dramaturgy of adaptations, especially in musical theatre. On the other hand, it has also brought some challenges: In terms of limitations, the reference search in this paper mainly focuses on literature review analysis. If there were interviews or questionnaire summaries, it might add more quantitative and qualitative analysis to support the result and conclusion. This is an aspect that can be improved.

My research findings contribute to the existing scholarship in the field of musical theatre and provide a keystone for further exploration and understanding of theatrical methods for adapting different source materials into musicals.

V. Conclusion

In conclusion, as a paper that links and explores the theatrical adaptation in musical theater, this paper provides insightful thinking and can further benefit and assistance to scholars studying dramaturgy and the production area of musical theater. The paper provides a longitudinal analysis of two Broadway musicals while introducing dramaturgy and the role of the dramaturg. Through relatively detailed analysis, the paper can attempt to help other scholars draw inspiration and generalize parts of similarities in the dramaturgical process in musical theater. At

the same time, this research is also a reflection on the content of musical theater, which can be detailed in Broadway-specific musicals, helping to preview and understand the characteristics and commonalities of the dramatic approach. At the same time, this research is also a reflection on the content of musical theater, which can be detailed in Broadway-specific musicals, helping to preview and understand the characteristics and commonalities of the dramatic approach. This paper helps outline the ways of adapting source materials into musicals and considers the approach and intention of dramaturgy which focuses on adaptation from a different perspective, prioritizing the music choice, narrative plot, and character development.

This paper focuses on exploring two world-renowned and representative works in adapted music, *Hamilton* and *Into the Woods*. While these works have already demonstrated distinctive characteristics not entirely captured in previous discussions, their approach to adaptation still offers valuable insights for readers and professionals in the theater industry as a reference for analyzing the dramaturgical process. The successful adaptation of a musical hinges on the dramaturgical process of thorough understanding, analysis, and interpretation of the source.

Based on the above research and conclusions, we will find that studying the nuancing of a narrative arc in musicals, although I don't focus on the exact dramaturgical practices used in these productions, I have described more outcomes on how the turn to certain elements of the production nuance the narrative arc. Dramaturgy remains a fascinating process full of infinite possibilities. After mastering the analysis, theater scholars may turn their attention to how to best adapt a musical through dramaturgical analysis or place this scenario in today's society to explore the changes and invariance of drama in the face of the rapid development of artificial intelligence, audience interests, and other different conditions from the past.

Theater scholars have an obligation to continue exploring the relationship between the original source and adaptation, from which not only can they obtain more conclusions about the correlation and causal relationship between the two, but perhaps there are also more unexplored perspectives and relationships between artistic role that's worth studying and documenting.

Understanding the dramaturgical process and working with the source material might open up questions regarding the generalization and transformation of musical theater adaptation, and other possible methods and approaches they would use to approach adaptations. Also, the paper opens the possibility that allows the researcher to investigate the dramaturgical process by looking at a musical's history, popularity, audiences, and different relations to the source

material. This investigation might change our relationship with the source material and allow us to conduct more research on how audiences understand perspectives through the expression of narratives of the source material.

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Schrödinger's Equation: Variations, Potentials, and Modern Applications

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2480 words

Abstract

Schrödinger's wave equation stands as a monumental foundation in quantum mechanics, presenting a framework that describes the evolution of quantum states across time. This research delves into the dynamic nature of Schrödinger's equation, emphasizing its adaptability when applied to various potential structures. The equation's utility is explored across different contexts, from infinite and finite potential wells to potential barriers and three-dimensional problems, each illustrating unique quantum phenomena such as discrete energy levels, quantum tunneling, and the probabilistic distribution of particles. Furthermore, this paper highlights the equation's application in avant-garde research fields such as quantum computing, where it provides essential insights into qubit behavior, and in material science, guiding the development of novel materials with bespoke quantum properties.

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1 Introduction

1.1 The Quantum Revolution

Quantum mechanics, a realm where the very fabric of nature reveals its probabilistic and wave-like character, underwent a revolutionary transformation with the advent of Schrödinger's wave equation in the early 20th century. This transformation was not just a leap in understanding the microscopic world but also a foundational shift in how physical reality is conceptualized. Schrödinger's equation, embodying the wave-particle duality, serves as a linchpin in the vast domain of quantum mechanics, offering a mathematical framework to predict the behavior of particles at the quantum level.

The narrative of quantum mechanics is punctuated by profound discoveries that challenged the classical conceptions of physics [1]. Before Schrödinger introduced his wave theory, our understanding of the tiny quantum world was shaped by Planck's ideas about energy coming in packets and by what we learned from the photoelectric effect, which Einstein explained (see Figure 1). The photoelectric effect is an experiment where light hits a surface and knocks out electrons, but only if the light is strong enough. This showed us that light acts like a bunch of tiny particles, called photons, and helped set the stage for the quantum theories that came later [1-3]. However, it was the formulation of the wave equation by Erwin Schrödinger in 1925 that provided a comprehensive mathematical structure for quantum mechanics. Schrödinger's equation emerged not only as a

theoretical construct but as a practical tool to unravel the mysteries of atomic and subatomic particles.

In this tumultuous era, the concept of wave-particle duality became a cornerstone of quantum theory, thanks to the pivotal experiments and theories proposed by physicists like Heisenberg, Bohr, and de Broglie [4,5]. These developments led to a new understanding of matter and energy, fundamentally altering our perception of the universe at its most elemental level.

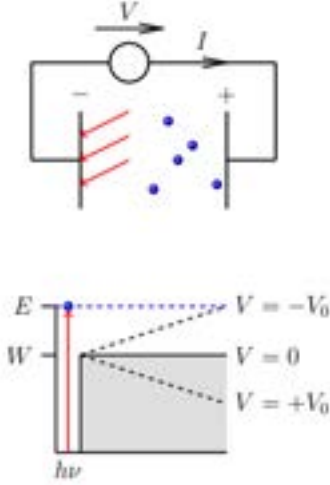


Figure 1: A diagram illustrating the photoelectric effect experiment. This experiment validated Einstein’s quantization hypothesis in which energy is discretized in packets, more commonly known as photons, with each photon carrying an energy of $h\nu$.

1.2 Introduction to Schrödinger’s Equation

In the midst of the quantum revolution, amidst the flourishing of ideas that would drastically alter our comprehension of the microscopic world, Erwin Schrödinger in 1925 proposed an equation that stands as one of the most significant contributions to the field of quantum mechanics. This section delves into the historical backdrop leading to the inception of Schrödinger’s wave equation and provides a concise derivation, illustrating its foundational role in quantum theory.

The journey to Schrödinger’s equation began with the failure of classical physics to explain phenomena at the atomic and subatomic levels [1]. Experiments such as the photoelectric effect, blackbody radiation, and the discrete lines of atomic spectra could not be accounted for within the classical framework. This led to the birth of quantum mechanics, a theory grounded in the quantization of physical properties. Max Planck’s hypothesis of quantized energy levels and Albert Einstein’s explanation of the photoelectric effect laid the groundwork [2,3]. However, it was Schrödinger’s wave equation that provided a comprehensive mathematical framework for quantum mechanics.

Schrödinger sought to describe particles not as discrete entities but as wave-like structures spread out in space. His inspiration came from the classical equation of a vibrating string, which is a partial differential equation describing the displacement of points on a string as a function of time. Schrödinger postulated that the behavior of quantum particles could be described by a similar wave equation. The

derivation of Schrödinger’s equation starts from the classical energy conservation equation, with a quantum perspective:

$$E = \frac{p^2}{2m} + V$$

where E is the total energy, p is the momentum, m is the mass of the particle, and V represents the potential energy. In quantum mechanics, energy and momentum are represented as operators. The momentum operator, in one dimension, is given by $\hat{p} = -i\hbar\frac{\partial}{\partial x}$, where \hbar is the reduced Planck’s constant and i is the square root of -1 . Substituting the quantum mechanical operators into the classical energy equation yields:

$$\hat{E}\Psi = \left[\frac{-\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + V \right] \Psi$$

Considering that the energy operator corresponds to the time derivative, $\hat{E} = i\hbar\frac{\partial}{\partial t}$, we obtain the time-dependent Schrödinger wave equation:

$$i\hbar\frac{\partial\Psi}{\partial t} = \left[-\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x^2} + V(x,t) \right] \Psi$$

This equation describes the evolution of the wave function Ψ , which encodes the probabilistic nature of the quantum state of a particle. For time-independent potentials, separating the variables allows for the derivation of the time-independent Schrödinger equation, essential for analyzing the stationary states of a system:

$$-\frac{\hbar^2}{2m} \frac{\partial^2\Psi}{\partial x^2} + V\Psi = E\Psi$$

Schrödinger’s wave equation revolutionized physics by providing a comprehensive mathematical framework for quantum mechanics, enabling the prediction of quantum phenomena with unprecedented accuracy. Through its solutions, the wave equation elucidates the probabilistic nature of particles’ behavior at the quantum level, offering insights into the fundamental principles governing the microscopic world.

1.3 Electrons as Both Waves and Particles: Introducing the Wavefunction

The concept that electrons exhibit both wave and particle characteristics is a fundamental principle in quantum mechanics, known as wave-particle duality [4]. This principle transcended classical physics’s distinct categories of ‘wave’ and ‘particle’ and fostered a new understanding of quantum entities. In 1924, Louis de Broglie proposed that particles could exhibit wave-like properties, suggesting that matter could behave similarly to light, which was already known to display both wave and particle traits.

Experimental evidence for the electron’s dual nature was famously provided by the double-slit experiment (see Figure 2). When electrons pass through two closely spaced slits and are detected on a screen, they form an interference pattern indicative of wave-like behavior. Yet, when measured individually, electrons reveal their particle-like aspects, imparting discrete impacts on the detecting screen.

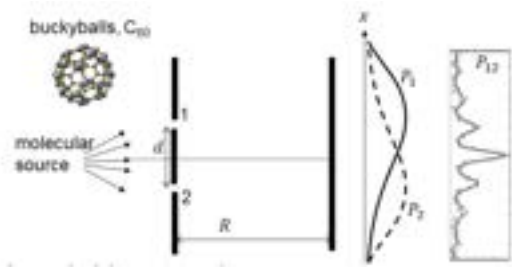


Figure 2: A diagram of the double-slit experiment utilizing buckyballs (C_{60} molecules) to demonstrate wave-particle duality. The diagram depicts the setup where a beam of buckyballs is directed towards a barrier with two slits, resulting in an interference pattern on the screen behind the barrier. This pattern of alternating light and dark fringes provides evidence for the wave-like behavior of large molecules, akin to the interference observed with light and electrons.

The mathematical representation of an electron's wave-like characteristics is encapsulated in the wavefunction Ψ , a complex function that contains all the information about the quantum state of an electron. The wavefunction is a core concept in quantum mechanics, explicitly formulated by the Schrödinger wave equation:

$$i\hbar \frac{\partial}{\partial t} \Psi(\mathbf{r}, t) = \left[-\frac{\hbar^2}{2m} \nabla^2 + V(\mathbf{r}) \right] \Psi(\mathbf{r}, t)$$

Here, \hbar signifies the reduced Planck's constant, m represents the mass of the electron, ∇^2 is the Laplacian operator affecting spatial variables and describing how the space around the electron influences its behavior, and $V(\mathbf{r})$ is the potential energy as a function of position.

1.4 Born Rule, Probabilities, and Normalization

The Born Rule is the postulate that connects these abstract wave functions to concrete probabilities [6]. It provides the probability density, $P(\mathbf{r}, t)$, that a particle is observed at the position \mathbf{r} and time t , which is given by the squared magnitude of the wave function:

$$P(\mathbf{r}, t) = |\Psi(\mathbf{r}, t)|^2$$

This squared modulus translates complex probability amplitudes into real, positive values that correspond to probabilities.

Normalization imposes the condition that the total probability of finding a particle somewhere in space is one:

$$\int |\Psi(\mathbf{r}, t)|^2 dV = 1$$

To maintain this constraint, wave functions must be properly normalized when they are used to predict physical phenomena. This is especially important when the wave function changes due to different potential energy functions $V(\mathbf{r})$ in Schrödinger's wave equation:

$$i\hbar \frac{\partial}{\partial t} \Psi(\mathbf{r}, t) = \left[-\frac{\hbar^2}{2m} \nabla^2 + V(\mathbf{r}) \right] \Psi(\mathbf{r}, t)$$

Different potential energy shapes lead to different wave functions, and thus, to different probability distributions.

2 Solutions to Schrödinger's Equation in Different Potentials

2.1 Motivation

Understanding the solutions of the Schrödinger equation under different potentials is crucial for several reasons [7]:

Understanding Electrons in Materials

At the heart of condensed matter physics is the study of electron behavior in various materials. The Schrödinger's equation, by predicting how electrons behave under different potential energies, enables us to understand fundamental properties of materials such as conductivity, magnetism, and superconductivity. This understanding is crucial for explaining phenomena like the quantum Hall effect and topological insulators.

Designing New Materials

The ability to predict the behavior of electrons under different potentials allows scientists and engineers to design new materials with desired properties. This is especially important in the development of semiconductors, photovoltaic cells, and batteries. By manipulating the potential landscapes within materials, we can tailor their electrical, optical, and magnetic properties, leading to innovations in technology and industry.

Serving as a Base to Solve More Complicated Scenarios

The Schrödinger's equation, in its simplicity, forms the groundwork for tackling more complex quantum mechanical problems [8]. Solutions in well-understood potential scenarios serve as a stepping stone for approximating solutions in more complicated, real-world situations. Techniques such as perturbation theory and the variational principle rely on these simpler solutions to approximate behaviors in more complex systems, including interactions between multiple particles or in the presence of external fields.

2.2 Infinite Potential Well

An infinite potential well, also known as a particle in a box (see Figure 3), is a fundamental problem in quantum mechanics that illustrates the concept of quantized energy levels.

Schrödinger's Equation and Boundary Conditions: The time-independent Schrödinger equation in one dimension is [8]:

$$-\frac{\hbar^2}{2m} \frac{d^2 \Psi}{dx^2} + V(x) \Psi = E \Psi$$

For $0 < x < a$, where $V(x) = 0$, the equation simplifies to:

$$\frac{d^2 \Psi}{dx^2} = -\frac{2mE}{\hbar^2} \Psi = -k^2 \Psi$$

where $k = \sqrt{\frac{2mE}{\hbar^2}}$. The general solution is:

$$\Psi(x) = A \sin(kx) + B \cos(kx)$$

Applying the boundary conditions $\Psi(0) = \Psi(a) = 0$ leads to the quantization of energy levels:

$$k = \frac{n\pi}{a}$$

$$E_n = \frac{n^2 \pi^2 \hbar^2}{2ma^2}$$

where $n = 1, 2, 3, \dots$ denotes the quantum number.

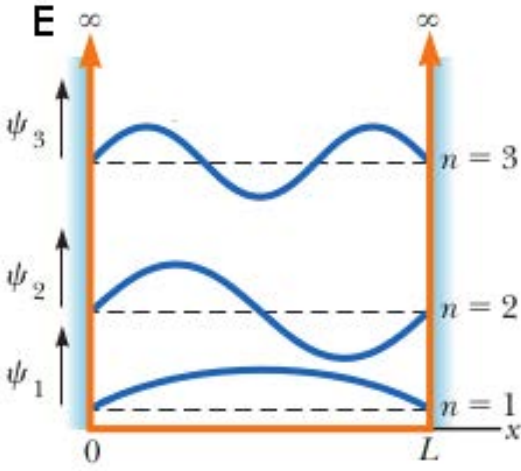


Figure 3: An infinite potential well, a conceptual model used in quantum mechanics to describe a particle that is confined to a region of space with impenetrable boundaries. The well is depicted with vertical lines representing the boundaries, which the particle cannot pass through, and a flat bottom indicating a region with zero potential energy. Within the well, the particle can only occupy certain energy levels, shown as horizontal lines, which correspond to the allowed quantum states of the particle.

2.3 Finite Potential Well

The finite potential well represents a scenario where a particle is trapped in a well with finite walls (see Figure 4). Unlike the infinite potential well, the particle has a non-zero probability of existing outside the well due to quantum tunneling.

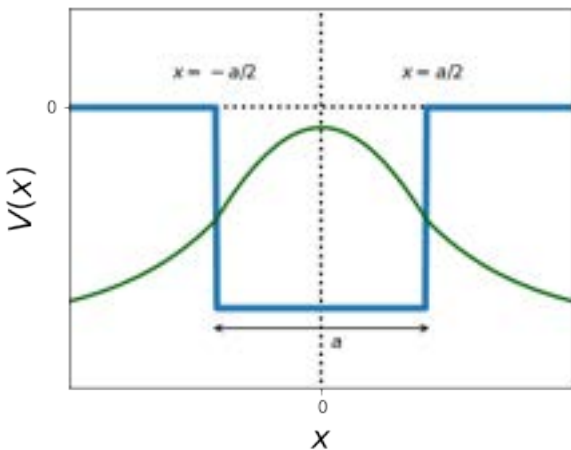


Figure 4: A graphical representation of a finite potential well, a quantum mechanical model used to describe a particle confined to a potential trough where it is energetically favorable to reside. Unlike the infinite potential well, the boundaries here are represented by finite potential barriers, suggesting that the particle has a non-zero probability of tunneling through these barriers.

The time-independent Schrödinger equation remains:

$$-\frac{\hbar^2}{2m} \frac{d^2\Psi}{dx^2} + V(x)\Psi = E\Psi$$

For $E < V_0$, within the well $0 < x < a$, the wavefunction solutions are given by a combination of sin and cos functions as in the infinite potential case. However, in the regions where the potential is non-zero, the solution takes the form:

$$\Psi(x) = Ce^{-\alpha x} + De^{\alpha x}$$

where $\alpha = \sqrt{\frac{2m(V_0 - E)}{\hbar^2}}$.

Boundary conditions at $x = 0$ and $x = a$ and the continuity of Ψ and $\frac{d\Psi}{dx}$ at the walls of the well give us the allowed energy levels, which remain discrete but less straightforward than the infinite well case.

2.4 Potential Step with ($E > V$) and ($E < V$)

For a particle encountering a potential step, there are two scenarios depending on whether the energy of the particle (E) is greater than or less than the step potential (V).

2.4.1 Scenario ($E > V$)

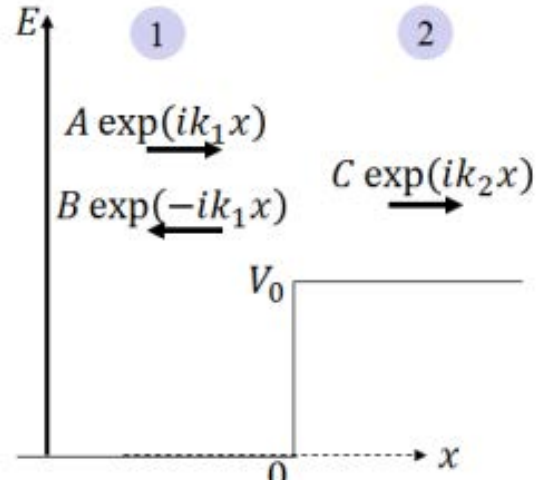


Figure 5: This figure illustrates a quantum mechanical scenario where the energy E of a particle is greater than the potential energy V of the barrier it encounters.

The wavefunction solutions on either side of the potential step are:

$$\Psi_1(x) = Ae^{ik_1 x} + Be^{-ik_1 x} \quad \text{for } x < 0$$

$$\Psi_2(x) = Ce^{ik_2 x} \quad \text{for } x > 0$$

where k_1 and k_2 relate to the energy and potential as $k_1 = \sqrt{\frac{2mE}{\hbar^2}}$ and $k_2 = \sqrt{\frac{2m(E-V)}{\hbar^2}}$. The coefficients A , B , and C are found using boundary conditions.

2.4.2 Scenario ($E < V$)

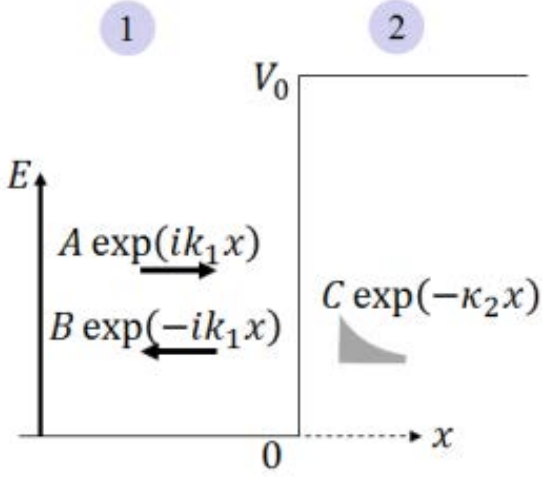


Figure 6: This figure depicts a quantum mechanical scenario where the energy of a particle, denoted by E , is less than the potential energy V of the barrier. In classical physics, a particle with insufficient energy would be unable to surmount the barrier. However, quantum mechanics allows for the phenomenon of quantum tunneling, where there is a probability that the particle can penetrate and cross the barrier despite having lower energy.

Here, the wavefunction within the region of the step ($x > 0$) decays exponentially as the particle exhibits tunneling:

$$\Psi_2(x) = D e^{-\kappa x}$$

where $\kappa = \sqrt{\frac{2m(V-E)}{\hbar^2}}$.

Boundary conditions are applied at the interface ($x = 0$) to match the wavefunctions and their derivatives.

2.5 Finite Barrier

This scenario describes a finite height and width barrier (see Figure 7) which the particle may tunnel through, reflect off, or transmit depending on its energy relative to the barrier height.

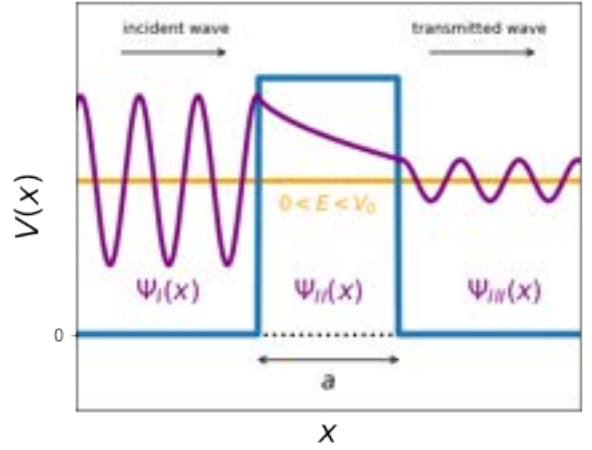


Figure 7: This figure illustrates the concept of a finite barrier potential in quantum mechanics. It shows a barrier with a specific height, representing the potential energy that a quantum particle must overcome. If a particle's energy is lower than the barrier height, it may still penetrate the barrier through quantum tunneling.

The time-independent Schrödinger equation is applied to both the free regions ($x < b$) and ($x > c$) and the barrier region ($b < x < c$). The general form of the wavefunction in each region is matched at the boundaries of the barrier, illustrating tunneling and reflection phenomena. Energy levels are not quantized in this scenario.

2.6 3D Schrödinger Equation

In three dimensions, Schrödinger's equation needs to accommodate the additional degrees of freedom and is given by [8]:

$$-\frac{\hbar^2}{2m} \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} \right) \Psi(\mathbf{r}, t) + V(\mathbf{r})\Psi(\mathbf{r}, t) = E\Psi(\mathbf{r}, t)$$

The solutions to the 3D Schrödinger equation are more complex because they depend on the specific form of the potential $V(\mathbf{r})$ [8]. For simple geometries like a cubic box, the solutions are separable in Cartesian coordinates (see Figure 8). For spherical symmetries, as in atoms, solutions are expressed in terms of spherical harmonics and radial functions.

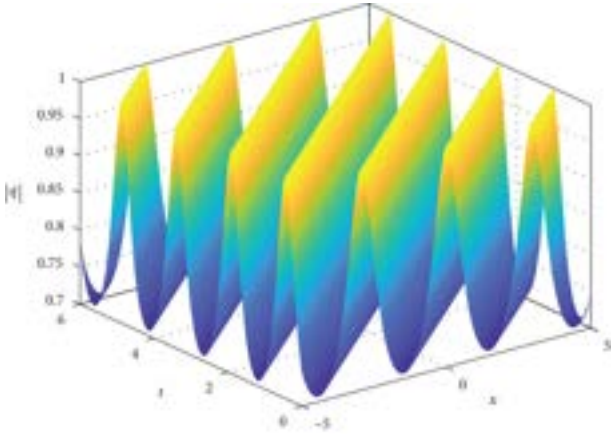


Figure 8: This figure provides an example of a three-dimensional (3D) wave function solution derived from Schrödinger's equation, which is central to quantum mechanics. The visualization captures the complex spatial form of a quantum wave function, with peaks and troughs representing the areas where the particle described by the wave function is more or less likely to be found.

3 Density Functional Theory (DFT)

3.1 Introduction to Density Functional Theory

Density Functional Theory (DFT) is a computational quantum mechanical theory used to investigate the electronic structure of many-body systems. It simplifies the complex problem of interacting electrons by focusing on the electron density, a function of three spatial coordinates, making it an essential tool for condensed matter physics, material science, and chemistry [9].

3.2 Theoretical Foundations

The journey from the many-body Schrödinger equation to DFT begins by considering that materials consist of electrons and nuclei. The Schrödinger equation for a system of interacting particles includes kinetic energy terms for both electrons and nuclei, as well as potential energy terms representing electron-electron, nucleus-nucleus, and electron-nucleus interactions. The many-body Hamiltonian is expressed as:

$$\hat{H} = -\frac{\hbar^2}{2m_e} \sum_i \nabla_i^2 - \frac{\hbar^2}{2M} \sum_I \nabla_I^2 + \sum_{i,I} \frac{Z_I e^2}{|\mathbf{r}_i - \mathbf{R}_I|} + \frac{1}{2} \sum_{i \neq j} \frac{e^2}{|\mathbf{r}_i - \mathbf{r}_j|} + \frac{1}{2} \sum_{I \neq J} \frac{Z_I Z_J e^2}{|\mathbf{R}_I - \mathbf{R}_J|}$$

The Born-Oppenheimer approximation allows us to focus on the electronic problem by assuming that the nuclear motion can be separated due to the large mass difference between electrons and nuclei. This leads to an electronic Hamiltonian:

$$\hat{H}_{el} = -\frac{\hbar^2}{2m_e} \sum_i \nabla_i^2 + \sum_{i,I} \frac{Z_I e^2}{|\mathbf{r}_i - \mathbf{R}_I|} + \frac{1}{2} \sum_{i \neq j} \frac{e^2}{|\mathbf{r}_i - \mathbf{r}_j|}$$

3.3 Many-Body Problem and Independent Electron Approximation

Solving the electronic Hamiltonian directly is intractable for systems with more than a few electrons. The independent electron approximation simplifies the problem by assuming that electrons do not interact with each other, which eliminates the electron-electron interaction term. However, this approximation ignores electron correlation, which is significant in real materials.

3.4 Inclusion of Electron-Electron Interactions

The Hartree-Fock method reintroduces electron-electron interactions by including a Fock potential, which accounts for the average effect of electron repulsion. It is expressed as:

$$V_{\text{Fock}}(\mathbf{r}_i) = \sum_j \left(\int \frac{e^2 |\psi_j(\mathbf{r}_j)|^2}{|\mathbf{r}_i - \mathbf{r}_j|} d\mathbf{r}_j - \int \frac{e^2 \psi_j^*(\mathbf{r}_j) \psi_i(\mathbf{r}_j)}{|\mathbf{r}_i - \mathbf{r}_j|} d\mathbf{r}_j \right)$$

This potential includes the Hartree term (classical electron-electron repulsion) and the exchange term (quantum mechanical exchange interaction). However, it still does not fully account for electron correlation.

3.5 Kohn-Sham DFT and the Exchange-Correlation Potential

The Kohn-Sham method of DFT introduces an effective potential $V_{\text{eff}}(\mathbf{r})$ that simplifies the many-body problem into a set of single-particle equations. This effective potential includes contributions from the external potential, the Hartree potential, and the exchange-correlation potential. The Kohn-Sham equations are:

$$\left[-\frac{\hbar^2}{2m_e} \nabla^2 + V_{\text{eff}}(\mathbf{r}) \right] \psi_i(\mathbf{r}) = \varepsilon_i \psi_i(\mathbf{r})$$

The effective potential $V_{\text{eff}}(\mathbf{r})$ is defined as the sum of the external potential $V_{\text{ext}}(\mathbf{r})$, which is typically due to the nuclei, the Hartree potential $V_{\text{H}}(\mathbf{r})$, and the exchange-correlation potential $V_{\text{xc}}(\mathbf{r})$:

$$V_{\text{eff}}(\mathbf{r}) = V_{\text{ext}}(\mathbf{r}) + V_{\text{H}}(\mathbf{r}) + V_{\text{xc}}(\mathbf{r})$$

The Hartree potential $V_{\text{H}}(\mathbf{r})$ accounts for the classical electron-electron repulsion and is given by:

$$V_{\text{H}}(\mathbf{r}) = \int \frac{e^2 \rho(\mathbf{r}')}{|\mathbf{r} - \mathbf{r}'|} d\mathbf{r}'$$

The exchange-correlation potential $V_{\text{xc}}(\mathbf{r})$ captures the complex quantum mechanical interactions between electrons beyond the classical repulsion and is derived from the exchange-correlation energy functional $E_{\text{xc}}[\rho]$ as its functional derivative with respect to the electron density:

$$V_{\text{xc}}(\mathbf{r}) = \frac{\delta E_{\text{xc}}[\rho]}{\delta \rho(\mathbf{r})}$$

By solving the Kohn-Sham equations self-consistently, we obtain a set of orbitals that are used to construct the ground-state electron density, which in turn allows us to determine the electronic properties of the system.

3.6 Exchange-Correlation Functional Approximations

The exchange-correlation functional $E_{xc}[\rho]$ is approximated using various models. The Local Density Approximation (LDA) and the Generalized Gradient Approximation (GGA) are two widely used approximations (see Figure 9). LDA assumes that the exchange-correlation energy at each point in space is that of a uniform electron gas:

$$E_{xc}^{\text{LDA}}[\rho] = \int \rho(\mathbf{r}) \epsilon_{xc}^{\text{hom}}(\rho(\mathbf{r})) d\mathbf{r}$$

GGA refines this by including the gradient of the electron density:

$$E_{xc}^{\text{GGA}}[\rho] = \int f(\rho(\mathbf{r}), \nabla \rho(\mathbf{r})) d\mathbf{r}$$

where f is a function that accounts for the inhomogeneity of the electron density.

3.7 Self-Consistent Solution of Kohn-Sham Equations

The Kohn-Sham DFT formalism requires a self-consistent solution of the Kohn-Sham equations. Starting with an initial guess for the electron density, one solves the Kohn-Sham equations to obtain a new set of orbitals $\psi_i(\mathbf{r})$, from which a new electron density is constructed:

$$\rho(\mathbf{r}) = \sum_i |\psi_i(\mathbf{r})|^2$$

This process is iterated until the input and output densities converge to a predetermined accuracy, yielding the ground-state electron density and energy.

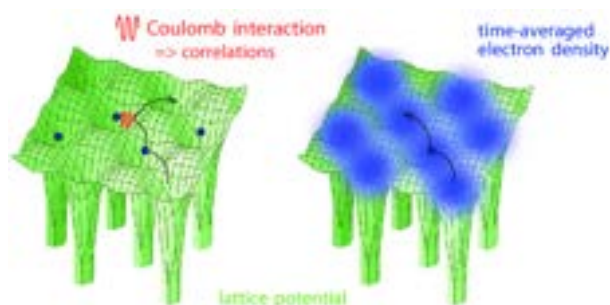


Figure 9: The many-body Hamiltonian schematically visualized. Black arrows represent the kinetic energy and the background ionic potential is shown in green. The Coulomb interaction (red) correlates the movements of the electrons. On the right, the dramatic simplification achieved by LDA is depicted. Each electron moves independently within a time-averaged local density of the other electrons.

4 Modern Applications in Contemporary Research

4.1 Quantum Computing and Information Theory

The Schrödinger wave equation and the extensions of it play a foundational role in quantum computing and information

theory. By describing the quantum states of particles, it allows for the development of quantum algorithms that leverage superposition and entanglement to solve problems intractable for classical computers. Research in this field often focuses on the development of quantum bits (qubits), quantum error correction, and quantum cryptography [10,11].

4.2 Material Science and Nanotechnology

In material science and nanotechnology, the Schrödinger equation is used to model the electronic properties of novel materials [7]. This includes the design of semiconductors, nanostructures, and photovoltaic materials (see Figure 10). The predictive power of quantum mechanical calculations based on Schrödinger's equation enables the discovery and optimization of materials with specific electronic, magnetic, and optical properties.

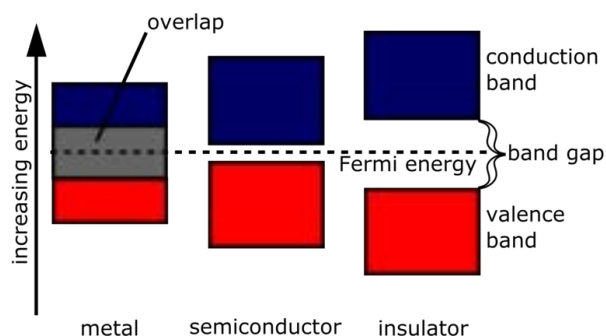


Figure 10: Schematic illustration of a semiconductor's electronic band structure. The valence band (VB) represents filled electron states, and the conduction band (CB) represents empty states. The energy difference between the VB and the CB is the bandgap (E_g), indicated by the horizontal gap. The Fermi level (E_F) is the energy at which the probability of finding an electron is 50%.

4.3 Drug Discovery and Molecular Biology

Schrödinger's wave equation is a critical tool in computational chemistry and molecular biology, particularly in the field of drug discovery [12]. Quantum mechanical simulations help in understanding the interactions between drugs and their target molecules, predicting the binding affinities, and identifying potential side effects. This approach accelerates the drug development process by reducing the reliance on empirical testing.

4.4 Chemical Reaction Dynamics

The study of chemical reaction dynamics relies heavily on the Schrödinger equation to model the behavior of electrons (see Figure 11) during chemical reactions [13,14]. This includes the exploration of reaction mechanisms, transition states, and the prediction of reaction rates. Quantum dynamics simulations provide insights into the fundamental processes that govern chemical reactivity.

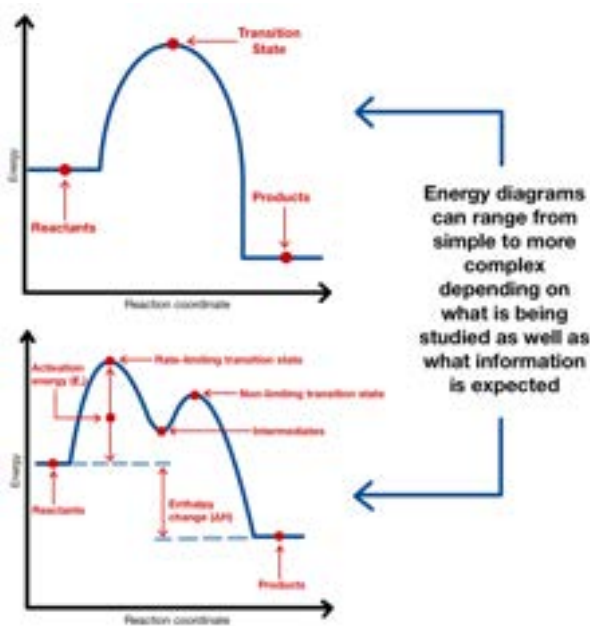


Figure 11: A graphical representation of the potential energy surface for a chemical reaction. The reactants (R) and products (P) are shown on the x-axis, with their corresponding potential energies on the y-axis. The transition state (TS) represents the highest energy point along the reaction pathway, requiring an activation energy (E_a) for the reaction to proceed. The arrows indicate the overall energy change (ΔE) during the reaction.

4.5 Astrophysics and Cosmology

Astrophysics and cosmology benefit from the Schrödinger equation in the study of quantum phenomena in extreme environments, such as white dwarfs and neutron stars [15,16]. The equation is also used in the context of dark matter research and the search for explanations of quantum gravitational effects in the early universe.

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