The Florida Atlantic Undergraduate Research Journal (FAURJ) was established through the Council of Scholarship and Inquiry, a registered organization of FAU's Office of Undergraduate Research and Inquiry. FAURJ is published each spring. Publication in the FAURJ is a year-long process that is possible through the efforts of our volunteer reviewers, contributing student authors, and dedicated editors. FAURJ expands the culture of undergraduate research and inquiry at FAU by showcasing student research across all disciplines.

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- Elon Musk
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Acknowledgements

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Letter from the Editors

We are proud to present to you volume seven of the Florida Atlantic Undergraduate Research Journal. The FAURJ is an interdisciplinary, peer-reviewed journal that is published annually. FAURJ is published online as well as in print and its mission is to showcase high quality undergraduate research in all fields, supply undergraduates with an idea of the standard of research, and promote inquiry-based activities at Florida Atlantic University.

The FAURJ is student-run by the Council for Scholarship and Inquiry (CSI), a registered student organization at FAU. The organization promotes and fosters a culture of research at the university across all disciplines. CSI strives to enhance scholarship, creativity, critical thinking and academic excellence of undergraduate students at FAU. Opportunities sponsored by CSI include publication in the FAURJ, student workshops, promotion of faculty-student interaction and peer mentoring. Undergraduate research provides students the ability to create and pursue innovative ideas under the mentorship of faculty members, which distinguishes FAU as a prestigious institution and shapes the young minds of the future.

We would like to thank all of the students who have submitted their work for the 2017-2018 publication. You all have shown immense dedication to your research and we wish you the best in your future endeavors. We hope you enjoy this edition of FAURJ, and encourage you to stay curious!

Luca Brunozzi & Makenzie Rynn
Artist Statement

As a physics major and a Biology B.S. degree holder, I have developed an in-depth passion for research and experimentation over my many years of undergrad. I believe that without research there is no innovation, and without innovation there is no progress. Here at FAU, we strive to continue the advancement in each field and work tirelessly to discover new perspectives. So, I am beyond appreciative to be a part of the developments in the physics and biological fields; the experiences have shaped my outlooks on life in many ways as I was repeatedly pushed to the limit in analytical thinking and endurance. Through the use of color, I wanted to express the mix of disciplines and personalities involved in the research showcased in the FAURJ. The image of the hand represents the many opportunities at our fingertips thanks to the vast array of resources available to us through our university. The quote I included by Elon Musk encompasses our passion and enthusiasm for research and pinpoints our motivation for our exhaustive efforts. We WILL shape the future.

Alexandra DeCesare
Charles E. Schmidt College of Science
Physics Major
This study presents a review of cases reported in the news media regarding unarmed black men shot and killed by police in the United States (U.S.) between the years 2011 and 2016. In the sampled cases, all police officers involved were acquitted following decisions from grand juries or district attorneys. This research comprises cases involving deaths of unarmed African-American males. Case data were collected from two prominent newspapers: *The Washington Post* and *The New York Times*. Analyzing these articles allows for a better understanding regarding the outcomes, effects, and the repercussions of the incidents in the African American community. By incorporating Critical Race Theory (CRT), this research will provide individuals with a better understanding of racism and discrimination that has been historically propagated by police forces, and its negative effect on Western society. By investigating police policies and procedures, as well high-profile incidents of police coercion, this study will reveal the extent of racially motivated police misconduct in the U.S.

This study incorporates a review of cases that were reported in the media between the years 2011 and 2016. These cases consist of police officers who were cleared of all criminal charges stemming from the deadly encounters with unarmed African American males. Case data were collected from two prominent newspapers - *The Washington Post* and *The New York Times*. By utilizing CRT and examining incidents of police misconduct, results will determine whether race plays a crucial factor in case outcomes involving African American victims.

This project also explores the possible reasons for a higher proportion of minorities being killed by police officers.

Critical Race Theory (CRT) is a fundamental framework used in the social sciences and the legal field to examine and analyze the reasons for such racial injustices in today’s society. CRT acknowledges that racism exists within societies and tends to be perceived as normal. The present study uses CRT to reveal the relative influence of race and power within the police force (Delgado and Stefancic 1995).
CRT also provides “a theoretical and interpretive mode that examines the appearance of race and racism across dominant cultural modes of expression” (Brizee, Tompkins and Chernouski 2015). By using CRT, one can develop a better understanding of racism and discrimination in policing and how they both have placed a negative impact on society. The American society has become addicted to violence. The relationship between African American and law enforcement has become not only increasingly brutal, but back-breaking (NORC at the University of Chicago 2015). This symbolizes that racism, white supremacist, and violence are interlocked, which means that they each have a lamentable effect on each other and they have all continued to permeate the American society in detrimental ways. Violence against minorities, especially African Americans, is not only a serious issue, but it also heightens the tension between law enforcement and the African American community.

The aim of this research is to provide insight regarding the research question and a contribution on how to solve these societal issues to create a better community. Between the years 2014 and 2015, police violence in the U.S. “generated a national conversation about the nature of America’s law enforcement” (Wang 2015, 1). The lives of residents are often not valued. Unfortunately, “no other country in the world imprisons so many of its racial or ethnic minorities” than the U.S. (McCoy 2014, 6). Police misconduct and violence are only symptoms of a larger societal issue: Institutionalized racism in the police force. While there are, many other challenging issues facing modern society, race plays a vital role in the cultivation of police brutality in the US. Studies have shown that by utilizing the theory of change, researchers have uncovered some of the reasons behind the perpetuation of racism, and white privilege in today’s world.

The theory of change (TOC) is a methodological tool used to develop long-term strategies and techniques in order to solve complex societal issues for a better tomorrow (Laing and Todd 2005). TOC also aims to unpack the process by which long-term change will occur and provides a dynamic outcome for future researchers to critique or pursue additional studies regarding such societal matters. In this study, TOC helps to analyze the dynamics of race and power by underpinning the functions of policing and the justice system in the U.S. The variables it investigates include the possession of power pertaining to police officers and the social scientific theories concerning police behavior. Subsequently, there are historical ties due to slavery. In his work, *Habeas Viscus: Racializing Assemblages, Biopolitics, and Black Feminist Theories of the Human*, author Alexander Weheliye discusses the historical significance of slavery, colonialism, segregation, and lynching. African Americans have always been classified as vulnerable, racially impure, and less than human in Western society (Weheliye 2014, 19). Thus, we live in a society where people of color are targeted as the victim of discriminatory crimes and activities, due to environmental destruction, poverty, and war (Smith 2005, 79).

Furthermore, CRT focuses on explicating factors that secure the predominantly white culture that has been fixed in its place in American society (Delgado and Stefancic 2012). This culture has and continues to benefit white people, while minorities continue to fail due to systematic oppression. By resolving these issues, one has to do so by promoting activism and challenging the norm (Delgado and Stefancic 1995). Therefore, “race undeniably plays a role in determining access to resources and power in American society” (Snyder 2013, 14). Whites have traditionally enjoyed higher class living and are treated as the more privileged and dominant racial ethnic group (Snyder 2013, 14). Hence, according
to defense lawyers, community activists, and civil libertarians, police brutality is starting to become more widespread and occurs over a hundred times per year in Long Island, with minorities seeming to be the most popular target. As a result, most of these incidents may go unreported because police officers are essentially the ones who investigate complaints regarding violence and disorderly conduct (Bessent and Taylor 1991).

**DISCUSSION**

This study presents a review of cases that have been reported in the media between the years 2011 and 2016. The cases discussed in this paper comprise unarmed African American men that have been beaten and killed by police officers because they seem to possess a weapon or some form of threat at the time. The following are the selected cases: Davon Mullins, Michael Brown, Tamir Rice, Anthony Robinson Jr., and Alfred Olango. This approach provides insight regarding the research question and a contribution on how to solve these societal issues in order to create a better community. These cases involve a pattern of unarmed black men being killed at the hands of law enforcement; and the officers were later cleared of all charges stemming from the arrests. For years, it has been very difficult to indict a police officer for wrongful death, due to qualified immunity in relation to use of force (Whether the officer’s force was reasonable), by the U.S. Supreme Court (Chemerinsky 2014). A landmark precedent that was used to determine that outcome was *Graham v. Connor*, 490 U.S. 386 (1989). Law enforcement officers are protected and exempt from being prosecuted for “violating constitutional principles that they could not have reasonably known at the time of the violation” (Deerrose 2016). An analysis of this generally consists of two issues to be decided by the Court: Firstly, as stated in Deerrose, 2016, did the officer’s conduct violate a constitutional right? And secondly, was that right established at the time such that the officer should have known of it? The Supreme Court strongly upholds that incidents involving the use of excessive force, deadly or not, by an officer should be scrutinized under the reasonableness standard of the Fourth Amendment (Deerrose 2016). Hence, the incident has to be carefully examined based on the nature and quality of the intrusion weighed upon applicable governmental interests (Deerrose 2016). Therefore, if an incident involving an officer was found to be objectively reasonable under the law, the officer would be acquitted.

Law enforcement and government officials are protected by qualified immunity and for that reason, many police misconduct or coercion incidents have been dismissed without a fair trial (Greenhouse 2001). In other words, the officer is absolutely protected under qualified immunity even when being sued for compensatory damages (Chemerinsky 2014). This ruling had a powerful effect on American society and the criminal justice system, and provides a reason why Officer Darren Wilson will never be charged for the death of Brown (Chemerinsky 2014). Officer Wilson can be charged with the death of Brown only if every reasonable officer would know that his actions established excessive force and not self-defense (Chemerinsky 2014). Both police officers and law enforcement personnel who are accused of perjury cannot be sued for compensatory damages because they are covered under the qualified immunity clause (Chemerinsky 2014). This helps to protect officials from harassment and liability when they perform their duties reasonably.

Figure 1 illustrates the findings of unarmed African Americans involved in deadly shooting incidents with officers. This study was conducted by
Mapping Police Violence (MPV) which is a research entity that collects and analyzes data on deadly shootings involving officers nationwide. Mapping Police Violence also confirmed that young black males between ages fifteen to nineteen were killed at a “rate of 31.17 per million, compared to “1.47 per million white males died at the hands of police” (Mapping Police Violence 2017). The graph above explains that African American people are five times more likely to die at the hands of police due to racial discrepancy in policing. While whites represent a majority of the population, blacks and Hispanics represent not only the minorities, but are also the victims of racial profiling and police coercion—armed or unarmed (Beer 2016). The main aim of this graph is to convey racial disparities among whites, blacks, Hispanics and law enforcement in the U.S. This information was collaboratively collected by three large databases that are constantly conducting research on police executions within the country: FatalEncounters.org, the U.S. Police Shootings Database and KilledbyPolice.net (Mapping Police Violence 2017). Mapping Police Violence’s (MPV) main aim is to continue extensive research on deadly shootings involving officers in order to improve the quality data findings and reports by media entities, police reports, and criminal records to retrieve the race of ninety-one percent of all victims in the database (Mapping Police Violence 2017).

MPV has also included data from the Bureau of Justice Statistics in order to efficiently cross-reference information across their studies. The bar graph in Figure 1 also concludes that of all reported incidents in 2015, 1 in 3 black people killed by police were considered unarmed and at least twice-a-week a hundred and two (minimum) unarmed black people are killed by law enforcement (Mapping Police Violence 2017). It was also reported that...
unarmed African American people were killed at five times the rate in comparison to unarmed whites (Mapping Police Violence 2017). Considering this, it was reported that officials of the City of Ferguson, Missouri, where the incident of Michael Brown occurred, have refused to address contravening acts which were later identified by the Department of Justice (Sussman 2016). The report later portrayed a pattern of inaccuracy by the Ferguson Police Department and the city’s municipal court pertaining to discrimination against African Americans, especially, unfairly targeting them for traffic stops, use of force and jail sentences (Sussman 2016). The report also concludes that the reason for such horrendous practices is shaped by law enforcement and officials’ need for revenue rather than for public safety needs (Sussman 2016). Based on the outcome of incidents involving police and unarmed deadly men, there seems to be more presumptive evidence than probable cause.

For instance, Officer Loehmann shot Rice because he thought that the toy gun that Rice was holding looked like an actual gun, which would be an example of reasonable suspicion (Blow 2015). Both Officer Loehmann and Garmback also refused to treat Rice medically or perform CPR (Blow 2015). Legal scholar Steven Schwinn argues that this should not be tolerated and is unacceptable (Schwinn 2014). According to the case of Terry v. Ohio, 392 U.S. 1 (1968), the Supreme Court ruled that law enforcement agents have a right to stop and frisk individuals due to reasonable suspicion (Search and Seizure 2009). The court refers to this activity as a Terry Stop which the court later identified as a form of impediment that does not violate the Fourth Amendment — the restriction of unreasonable search and seizure (Search and Seizure 2009). The court refers to this activity as a Terry Stop which the court later identified as a form of impediment that does not violate the Fourth Amendment — the restriction of unreasonable search and seizure (Search and Seizure 2009). Moreover, individuals are not required to identify themselves due to a ruling in the case of Hiibel v. Sixth Judicial District Court of Nevada, 542 U.S. 177 (2004) (Search and Seizure 2009). Officers are trained and are well aware that individuals may not be arrested due to reasonable suspicion. Instead, arrests are made based on probable cause. However, if probable cause develops during an investigatory stop, the officer may arrest the suspect (Search and Seizure 2009). Hence, officers are trained not to pursue lethal force as an option during such activities unless individuals are portrayed as an immediate risk or threat to law enforcement or others in the community.

Officers should also be held accountable for actions involving reasonable suspicion as well. Although reasonable suspicion comprises a lower threshold than probable cause, it is still an effective legal method that is covered under the Fourth Amendment (Schwinn 2014). For that reason, an officer has the power to stop a vehicle based on reasonable suspicion that a crime has been committed (Schwinn 2014). Reasonable suspicion also incorporates the ideology of a reasonable mistake of fact. While interrogating individuals during investigatory stops, reasonable suspicious may escalate tension between the officer and the civilian which may cause racial profiling or misconduct. Consequently, minorities, especially African Americans are more likely to be affected by these instances or incidents. Previous studies conclude that these attacks or incidents involving law enforcement and unarmed African-American men are possibly influenced by racial prejudice (Raasch and Perron 2014).

Cases of unarmed black men are not only increasing, but they are also threatening to the public, especially the black community. Law enforcement is visualized and portrayed as a protector of the people and the community. Police officers are trained to protect the community, but have become known for participating in horrendous activities involving misconduct and coercion. Society has
scrutinized the abusing actions of police officers towards citizens, especially when those citizens have been fatally shot and they are later declared unarmed and innocent. Most of these violent incidents took place because the officer used racial profiling as a factor when arresting the suspect. For that reason, the U.S. Supreme Court ruled in the case of *Tennessee v. Garner*, 471 U.S. 1 (1985) that the Fourth Amendment prohibits “the use of deadly force to effect an arrest or prevent the escape of a suspect unless” the officer fairly agrees that the individual has committed or attempted to commit a crime involving any form of infliction or significant physical injury and the cautious use of intentional deadly physical force given, whenever attainable (Coppolo 2008). Thereby, statutory laws regarding the use of deadly force seem to duplicate federal standards (Coppolo 2008). In the end, these incidents leave residents questioning the intentions of law enforcement and have had a negative psychological impact on the African-American community.

**IMPLICATIONS FOR REDUCING POLICE COERCION**

This project highlights a few implications for law enforcement practice to address growing concerns about police violence. Based on the data that have been collected and analyzed, this study provides five important implications to law enforcement in order to better their relationship with the community and lower the number of incidents that occur (especially involving unarmed black males). Of course, one may agree that American society has improved regarding racial equality, especially since the Jim Crow Era. However, in terms of community perceptions towards police in disadvantaged urban neighborhoods, one might argue that things have gotten worse, and that are large segment of minority communities still suffer the effects of concentrated disadvantage. There are several suggestions to consider: Upon entering the academy and the force, officers should complete a thorough background check, as well as psychological and polygraph examinations; police training needs to be reorganized so that it addresses cultural differences in behavior, such as, how to work with mentally compromised individuals, when to use reasonable or excessive force, and how to employ better communication techniques and strategies; effective training needs to be prioritized by police leaders, and they can also encourage officers on the beat to foster positive relationships with the public.

**RECOMMENDATIONS FOR FUTURE RESEARCHERS**

Despite decades of research on police brutality and minorities, violent interactions between law enforcement and the African-American community persist. Future researchers may consider implementing new and progressive police practices in black neighborhoods. Researchers can be embedded within law enforcement agencies and encouraged to conduct studies in partnership with police departments on police-citizen encounters. Interactions can be rated based on a range of factors with a special focus on the treatment of racial minorities. Researchers can also incorporate qualitative field research studies with racially diverse samples in order to analyze different perspectives and opinions pertaining to police coercion. Police recruitment and training can also be scrutinized and evaluated to increase knowledge on daily police routines.

Furthermore, while observing police departments, researchers can obtain permission to gather data from cases involving unarmed black men that are currently being investigated. Today, there is a need for clarification on police use-of-force and
minorities. After reviewing over a decade of peer-reviewed studies, a 2010 study published in the Southwest Journal of Criminal Justice concluded that there was a correlation between minorities and police use-of-force. Other studies did not confirm these findings, and yet others have shown mixed results (Ruth 2015). There is still a need for a more developed methodology that can provide more accurate results on the use-of-force by police officers during encounters with minorities. Researchers can consider qualitative interviews with new recruits to assess perspectives on attitudes regarding policing discretion and use-of-force decisions.

A 2012 study in Criminal Justice Policy Review (Ruth 2015), found patterns of behavior in a large police department where a small number of officers were frequently involved in use-of-force incidents. There were similar findings in a 2007 study in Criminal Justice and Behavior (“Police Education, Experience and the Use of Force”). It determined that officers who are more experienced and educated are less likely to use force unjustifiably (Ruth 2015). On the other hand, a review of case studies indicates that lack of training programs and accountability structures can heighten the use of violence by police departments (Ruth 2015). There is clearly a need for further study on the differences between officers’ behavior based on training and experience.

Despite inconclusive evidence, the majority of studies concluded that race has become a crucial factor in the criminal justice system. Minorities, especially African Americans, are more likely to receive harsher sentences “for assaults on whites, than on whites committing the same offenses” (Walker 2011, 576). Race, class, and gender privilege, are all discriminatory factors that play a vital role in systematic oppression and identity (Walker 2011). Incidents involving unarmed black men being shot or killed by police in the media may lead civilians to question the innocence of the black man and assumes that officer is the good guy (Walker 2011). Civilians draw their own conclusions about the justifiable use-of-force by police officers, and though such conclusions are often influenced by news media depictions, they are also influenced by longstanding stereotypes that perpetuate victim-blaming (Walker 2011). According to Walker, these attitudes and perceptions have been “ingrained since slavery, (and) nurtured and manipulated by the police, who are quick to release the prior-arrest or medical record of their victims [in order to] somehow justify [y] being killed by the police” (Walker 2011, 576). Furthermore, a 2014 Department of Justice (DOJ) study, which incorporates a two-year investigation, shows that the Albuquerque, New Mexico, police department violated the Fourth Amendment due to continuous practices of the use of excessive force (Ruth 2015). Likewise, a 2014 DOJ study concluded that the Cleveland police department violated the Fourth Amendment due to continuous practices of the use of excessive force (Ruth 2015).

In 2015, the DOJ findings also produced an alarming pattern of “clear racial disparities” and “discriminatory intent” by the Ferguson, Missouri, police department (Ruth 2015). For this reason, researchers may consider examining data from police departments such as Ferguson, Missouri, which have been under Federal oversight, to see whether they are sustaining changes made in the aftermath of tragic events and racially insensitive practices. More sophisticated analysis approaches can be included in order to determine whether there has been a decrease in the number of incidents that involve police shootings of unarmed black men. This research may produce policy recommendations for implementing new and effective technological tools and educational resources that may help prevent such incidents from increasing.

Based on past studies of police brutality, the degree to which race, and social status (e.g.
bourgeoisie) influence outcomes of police violence and aggression towards minority young men is still unclear (Brunson and Miller 2006). Many conclude that racial profiling is the main problem, and law enforcement leaders may consider incorporating evidence-based practices in order to implement solutions to reduce police brutality incidents over time (Magaloni, Franco and Melo 2015). Dr. Beatriz Magaloni, an associate professor of political science at Stanford, made such recommendations based on studies in Rio de Janeiro, Brazil (Magaloni, Franco and Melo 2015). Magaloni sought to explain why 5,132 civilians were killed by police between the years 2005 and 2014 (Magaloni, Franco and Melo 2015). Despite the differences between Rio de Janeiro and major American cities, the findings showed similar trends regarding police brutality towards minorities, especially in marginalized and predominantly black communities (Magaloni, Franco and Melo 2015). Magaloni’s work prompted changes in regard to strategies for preventing police coercion incidents and other violent incidents that contribute to a culture of violence (Magaloni, Franco and Melo 2015). As stated earlier, improving methodologies and data analysis techniques in the criminal justice field will help to reduce tragic incidents involving police and residents. It is hoped that such approaches may also lead to greater confidence in law enforcement within the communities that they serve.

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I would first like to thank my research mentor Dr. Vaughn Crichlow, of the School of Criminology & Criminal Justice at Florida Atlantic University (FAU). Dr. Crichlow has always been supportive whenever I needed help or expressed interest regarding my research or writing. Although I lacked experience in research writing, he allowed this paper to be my own work, but challenged me when necessary, for me to grow and gain the experience I need for Law School. I would also like to thank the Office of Undergraduate Research and Inquiry (OURI) and the FAU Wave program for awarding my research and supporting my work. This experience has helped me to develop both personally and professionally.

BIBLIOGRAPHY


A Mathematical Model Based on IC₅₀ Curves To Predict Tumor Responses to Drugs

Catherine I. Berrouet ¹, Jacob Nadulek ¹, Emmanuel Fleurantin ¹, Sunil Giri ¹, Katarzyna A. Rejniak ², & Necibe Tuncer

Traditionally, the monolayer (two-dimensional) cell cultures are used for initial evaluation of the effectiveness of anticancer therapies. In particular, these experiments provide the IC₅₀ curves that determine drug concentration that can inhibit growth of a tumor colony by half. The multicellular spheroid (three-dimensional) cultures have a histological and biochemical advantage over two-dimensional cultures for cancer models due to the fact that gene-expression patterns in spheroids are more similar to those observed in real tumor samples. However, three-dimensional cultures are time consuming, costly and laborious. Therefore, it is crucial to develop a mathematical model to investigate how to use information from the IC₅₀ approach to predict how a three-dimensional tumor will respond to the treatment. One of the goals of this study is to answer the question if the IC₅₀ concentration assessed from the two-dimensional cell culture will be sufficient enough to kill half of the cells in a three-dimensional spheroid? Another question is to determine whether there is a mathematical way to scale the IC₅₀ concentration to be effective towards the three-dimensional case. Using the individual-cell-based model we address these questions and our results have shown that in both models as the diffusion rates increase the IC₅₀ values decrease. Furthermore, the IC₅₀ value for the three-dimensional model is two order of magnitude higher than the IC₅₀ value of two-dimensional model. This comparison of the cellular growth in the two- and three-dimensional cases under treatment showed that if the drug diffusion rates are higher, then there is greater likelihood of reducing tumor growth using drug concentrations that are lower, hence less damaging to cancer patients.

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INTRODUCTION

For many years, various clinical therapies have been developed to treat cancer. Extensive research is continually being conducted to find more efficient and less toxic treatments. Chemotherapy, the systemic administration of anticancer drugs, remains the most common form of treatment for most kinds of cancer. The three main goals for chemotherapy are to cure cancer, control the disease or possibly to palliate, and ease the symptoms caused by cancer [1]. However, chemotherapy drugs target cells at different phases of the process of forming new cells, called the cell cycle [1]. While gene expression is the process by which information from a gene is used in the synthesis of a functional gene product. These products are often proteins, which are also used in cancer research to understand the cell binding and attachments of drugs administered [2]. Understanding how these drugs work helps doctors predict which drugs are likely to work in synergism. Doctors can plan how often doses of each drug should be given based on the timing of the cell phases. Cancer cells tend to form new cells more quickly than normal cells and this makes them a better target for chemotherapy drugs [2]. However, these drugs do not differentiate between healthy cells and cancer cells. This means normal cells are damaged along with the cancer cells, and this causes side effects. For each dose of chemotherapy there needs to be a balance between killing the cancer cells (in order to cure or control the disease) and sparing the normal cells (to lessen side effects). This is why inhibitory concentration curves are created and studied. Typically, the dose-response curve constructed, the inhibitory concentration (ICx) curve of a drug, can be determined by examining the effect of different concentrations of antagonist on reversing agonist activity. IC_{50} values can be calculated for a given antagonist by determining the concentration needed to inhibit half of the maximum biological response of the agonist. Furthermore, IC_{50} values can also be used to compare the potency of two antagonists [3]. In our study, the half maximal inhibitory concentration curves, denoted by IC_{50'}, are the measurement of drug concentration that inhibits growth of cancer cell colony by 50% [4]. The goal of this study is to create a mathematical model to predict tumor responses to drugs based on these IC_{50} curves. We analyzed IC_{50} curves in relation to different parameters in order to maximize efficiencies in cancer drug treatments. We used the IC_{50} value generated by a two-dimensional (2D) model and to compare the tumor response in a three-dimensional (3D) model. The models are described further in section II, Methods: Developing the Mathematical Model. We hypothesized that if the drug diffusion rates are higher for both models, two-dimensional and three-dimensional case, then cellular growth will be reduced by half using higher drug concentrations.

METHODS: DEVELOPING THE MATHEMATICAL MODEL

Our approach is to use an individual-cell-based model, that is a discrete model, coupled with diffusion equations to describe the interplay between tumor cell growth and drug uptake. First, let’s discuss cell duplication. One cell cycle consists of two general phases: interphase, followed by mitosis and cytokinesis. Interphase is the period of the cell cycle during which the cell is not dividing. The majority of cells are in interphase most of the time. Mitosis is the division of genetic material, during which the cell nucleus splits into two new fully functional nuclei. This is what we’ve referred to as the “mother” and two “daughter” cells. Cytokinesis divides the cytoplasm into two distinctive cells. A very elaborate
and precise system of regulation controls direct
the way cells proceed from one phase to the next
in the cell cycle and begin mitosis [1]. The control
system involves molecules within the cell as well as
external triggers. These internal and external control
triggers provide “stop and advance” signals for the
cell. Precise regulation of the cell cycle is critical for
maintaining the health of an organism, and loss of
cell cycle control can lead to cancer.

Next we discuss the development of our individu-
ual-cell-based model. To develop our discrete
mathematical model, we represent cells by their
nuclei and cell radius, and considered Newton’s law
of motion to define repulsive forces that preserve
cell size, as well as the diffusive transport of drug
within the cell cultures. This model is based on the
work in [4]. In general, let \( C_i(t) = (x_i(t); y_i(t); z_i(t)) \)
and \( C_j(t) = (x_j(t); y_j(t); z_j(t)) \) be the location in 3
dimensions of cells \( C_i \) and \( C_j \) at time \( t \). By Newton’s
law, we have that \( F = m \cdot a \) where \( F \) is the force, \( m \) is
the mass, and \( a \) represents acceleration. Acceleration
is directly related to the viscosity of the medium in
which the cells reside, which is a measure of a fluid’s
resistance or thickness. The less viscous the fluid is,
the greater the fluidity or ease of movement there is
within it. Hence, Newton’s law used for our simula-
tions, using MATLAB software, are coded using the
equation:

\[
F = m \cdot a = m \cdot \frac{d^2 \bar{C}_i}{dt^2} = F_i + F_i^{\text{viscosity}} \quad (a)
\]

\( F_i \) is the force exerted on the \( i^{\text{th}} \) cell by their neigh-
bors, and is a sum of forces exerted by individual
cells. We define the force exerted on the \( i^{\text{th}} \) cell by
the \( j^{\text{th}} \) cell to be \( f_{i,j} \). We assume the interaction forces
\( f_{i,j} \) are linear and use Hooke’s Law (which states that
the force needed to extend or compress a spring by
some distance scales linearly with respect to that dis-
tance) with the spring constant denoted by \( F_{spr} \). So
the equation of the forces from several neighboring
cells takes the following form:

\[
F_i = f_{i,j} + \ldots + f_{i,N} = \sum_{j=1}^{N} f_{i,j} \quad (b)
\]

where

\[
f_{i,j} = \begin{cases} 
F_{spr}(2R_C - ||C_i - C_j||) & \text{if } ||C_i - C_j|| < 2R_C \\
0 & \text{otherwise,}
\end{cases}
\]

using distance formula, between two cells \( C_i \) and \( C_j \):

\[
||C_i - C_j|| = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}
\]

Where radius of the cell is denoted by \( R_C \). The num-
ber of neighboring cells are important to calculate
the forces exerted on a cell during cell division and
movement. Therefore, we determine the neighbor
cells by checking the distance between the mother
(initial) and daughter cell, using the distance for-
mula as expressed above in (b). In other words, the
neighbor cell \( C_j \) is determined by the distance
between it and cell \( C_i \). More specifically, all the cells
that are within \( 2R_C \) distance from \( C_i \) are all neigh-
bors. Otherwise, if the distance by the cells \( C_i \) and \( C_j \)
are greater than \( 2R_C \) then the forces \( f_{i,j} \) are set to zero.

Now, the viscous force is the force between a body
and a fluid medium that provides resistance to cell
movement. Thus, the fluid is moving in a direction
opposite to the cell, that is, its drag force. From [6]
we have that the viscous force is generated by a com-
bination of cell-cell, cell-medium and cell-matrix
interactions and is modeled by assuming that the
drag force is proportional to its velocity (cell viscos-
ity coefficient).

\[
F_i^{\text{viscosity}} = -\xi \frac{dC_i}{dt}
\]

Then cell relocation is governed by the following:
Since \( \frac{dC_i(t)}{dt} = \lim_{\Delta t \to 0} \frac{C_i(t + \Delta t) - C_i(t)}{\Delta t} \) in our discrete model, we approximate the derivative by its difference quotient. Hence, \( \frac{dC_i(t)}{dt} \approx \frac{C_i(t + \Delta t) - C_i(t)}{\Delta t} \). Suppose that \( \frac{d^2C_i}{dt^2} = 0 \). Then by (a) and (b), we obtain: \( F_i + F_i^{\text{viscosity}} = m \cdot 0 \). Substituting (b) and (c), we have \( \Sigma_{j=1}^{N} f_{i,j} \)

Subtracting (b) from both sides \( \Rightarrow \frac{\xi C_i(t + \Delta t) - C_i(t)}{\Delta t} = -\Sigma_{j=1}^{N} f_{i,j} \)

Multiplying both sides by \( \Delta t \) \( \Rightarrow \xi C_i(t + \Delta t) - \xi C_i(t) = -\Delta t \Sigma_{j=1}^{N} f_{i,j} \)

Adding \( \xi C_i(t) \) to both sides \( \Rightarrow \xi C_i(t + \Delta t) = \xi C_i(t) - \Delta t \Sigma_{j=1}^{N} f_{i,j} \)

Finally, we have our equation for cell relocation \( \xi \in (t + \Delta t) = \xi C_i(t) - \Delta t \Sigma_{j=1}^{N} f_{i,j} \)

Recall, we let \( C_i(t) = (x_i(t), y_i(t), z_i(t)) \) and \( C_j(t) = (x_j(t), y_j(t), z_j(t)) \) be the location in 3 dimensions of cells \( C_i \) and \( C_j \) at time \( t \). Now, from [5], each cell \( C_i(t) \) is defined by its position \( (x_i(t), y_i(t), z_i(t)) \), and is characterized by several properties, such as current cell age \( C_i^{\text{age}} \), and cell maturation age at which the cell is ready to divide, we denote as \( C_i^{\text{mat}} \). When the cell \( C_i(t) \) divides, one of its daughter cells \( C_{i_1}(t) \) takes the coordinates of its mother cell, we represent this behavior like so in our MATLAB code:

\[
(x_{i_1}(t), y_{i_1}(t), z_{i_1}(t)) = (x_i(t), y_i(t), z_i(t))
\]

whereas the second daughter cell is placed randomly near the mother cell:

\[
(x_{i_2}(t), y_{i_2}(t), z_{i_2}(t)) = (x_i(t), y_i(t), z_i(t)) + (\Delta x, \Delta y, \Delta z)
\]

determined randomly

Initially, the current age of both daughter cells is set to 0, and the cell maturation age is inherited with a small noise term. This means cells that reach maturation age divides and splits into its daughter cells, the daughter cells replace the position of the mother cell with the same random noise. Drug kinetics within the computational domain and its cellular uptake are defined as follows: Let \( u(x(t), y(t), z(t)) \) represent the drug concentration at position \( (x(t), y(t), z(t)) \) at time \( t \). Let \( D_u \) denote the drug diffusion coefficient, \( \rho_u \) drug uptake rate, and \( d_u \) drug decay rate, and let \( C_i^u(t) \) denote the amount of drug concentration of the \( i \)th cell at time \( t \). Then the rate of change of the drug concentration on the \( i \)th cell is given by \( \frac{dc_i^u}{dt} \), which is

\[
\frac{dc_i^u}{dt} = \text{input rate of drug - output of drug.}
\]

\[
\frac{dc_i^u}{dt} = \max(\ 0, \sum_{x,y,z} \min([u(x(t), y(t), z(t)], \rho_u) - d_u C_i^u(t))
\]

Similarly, \( \frac{dc_i^u}{dt} \) is approximated by its difference quotient,
We now look at drug diffusion. We assume that the diffusion coefficient, \( D_u \), is constant, and does not depend on time. Let \( u(x(t), y(t), z(t)) \) be the drug concentration at position \((x(t), y(t), z(t))\) at time \( t \). From Fick’s Law we approximate the second partial derivative \( \frac{\partial^2 u}{\partial x^2} \) by second order centered finite difference formula which is given by

\[
\frac{u(x(t + \Delta t), y(t + \Delta t), z(t + \Delta t) - u(x(t), y(t), z(t))}{\Delta t} \approx u(x + \Delta x, y, z) - 2u(x, y, z) + u(x - \Delta x, y, z) \frac{1}{(\Delta x)^2}
\]

\[
+ \frac{u(x, y + \Delta y, z) - 2u(x, y, z) + u(x, y - \Delta y, z)}{(\Delta y)^2}
\]

\[
+ \frac{u(x, y, z + \Delta z) - 2u(x, y, z) + u(x, y, z - \Delta z)}{(\Delta z)^2}
\]

That is:

\[
(3)
\]

Let \( u(x(0), y(0), z(0)) = u_0(x, y, z) \) denote the initial drug concentration. Using the individual-cell-based model equations (a) -- (3), we implemented two models in MATLAB, which we refer them as 2D and 3D models. In the 2D model, the drug concentration is evenly distributed to the whole domain where the cells are located (since cells are defined as its location). In the 3D model the drug is administered from the boundary of the domain and drug diffuses to the cells. The 2D model represents the Petri dish experiments (see Figure 1(a)) and the 3D model represents the cross-section through the three-dimensional spheroids (see Figure 1(b)). Using these two models we conducted several simulations to analyze in depth cellular responses to the drug dosage administered. Equations 1-3 are implemented in MATLAB to run the simulations. Each simulation represents a 72 hour period of cellular growth after a specific drug dosage is administered. Cells duplicate so the number of cells in the domain changes in time. So to compute IC_{50} curves, we count the number of cells remaining after 72 hours (hence, we record the number of cells remaining after each simulation).

Now we discuss the parameters used for our model. The standard procedure for growing cell colonies in monolayers (in a Petri dish) uses a 72-hour time frame [1]. To create a realistic initial cell count for our discrete model, we began to analyze cellular growth and how cells duplicate with respect to time. For our model, cellular growth is dependent upon drug absorption and cellular movement. Using MATLAB to run our two-dimensional and three-dimensional models, we recorded the number of cells remaining after the simulated 72 hours when no drug was administered, the 2D model generated 285 cells while the 3D model generated 165 cells, setting these value as our normalization cell count for all future simulations (Chart 1) respectively. Our first initial set of simulations were to focus on the effects of drug dosage alone. Thus, we fixed the diffusion coefficient, \( D_u = 0.75 \), for each simulation that tested various drug dosage (\( u_0(x, y, z) \)) (Figure 2). After completing a set of simulations, we then generated our IC_{50} curve. Each IC_{50} curve is computed in the following way: each point plotted is a computed ratio between the initial cell count (normalization cell count) and the cells that remained at the end of the 72-hour simulation. Hence, each point plotted is the representative percentage of cells after one complete simulation, according to it’s respective administered drug dosage. Next, we recorded a set
of simulations with fixed diffusion coefficients and varying drug dosages (Figure 4 & 5). For numerous diffusion coefficients fixed between 0 and 1 (Figure 5 & 6), we tested each \( D_u \) with different drug dosages \( (u_0(x, y, z)) \). Then the inhibitory concentration curves were generated for each of these cases as well. As a pseudo-algorithm: in all 2D cases we seed 285 number of cells; while in all 3D cases we seed 156 number of cells. And the initial drug concentration \( u_0(x, y, z) \) was varied between 0.01 and 0.09 for 2D model in different simulations (respective to each drug dosage administered). Similarly, in 3D, the initial drug concentration was varied between 0.1 and 100, in different simulations. All model parameters are summarized in Table 1. This mathematical model has been discretized using the standard finite difference methods, and parameters were chosen such that the numerical stability is preserved \( \Delta t \) and \( \Delta x \) are the numerical time step and grid width, respectively.

RESULTS

Without any drug administered to the system, that is, setting \( (u_0(x, y, z)) \), there were at least 84 cells generated on average from 24 to 36 hours (Chart 1). From the simulations throughout each time interval: for time \( t \) in hours, when \( t=24 \) there are about 90 cells generated, when \( t=24+C^{age} \) there were 83 cells generated, and when \( t=36 \), there were about 79 cells generated. Where \( C^{age} \) is randomly generated (determined by using the MATLAB rand function which uses a uniform distribution). Hence, for both models, we fixed the initial cell count at 100. Now, to test drug effectiveness, is to count how many cells die when exposed to various drug concentrations. Dose refers to the amount of a substance that is introduced to the organism. Generally, different drug doses can exert very different effects on the growing cells. Very low doses of some compounds can even induce stronger cellular responses than much higher doses and may result in different killing impacts. In Figures 2 and 3 we examine cellular responses to gradually increasing drug dosages in both the 2D and 3D models, and determine the IC\(_{50}\) value in both cases. These simulations indicate that in the 2D model drug dosage necessary to kill half of the initial population is much smaller in comparison to the drug dosage amounts necessary in the 3D model. In fact it is two order of magnitude smaller. These results led us to our next question: How does this relate to diffusion? Since diffusion is the process by which molecules of higher concentration move to areas of lower concentration, we varied \( D_u \) (the diffusion coefficients) over a range of values and analyzed how the inhibitory curves changed with increasing drug dosages. Figures 4 and 5 show the IC\(_{50}\) curves generated for various diffusion coefficients over the same ranges of drug dosage. All cell counts are normalized to the number of cells surviving a very small drug dosage of 0.01mg. In the three-dimensional model, with a very small drug dosage of 5mg, \( D_u=0.85 \) and \( D_u=1 \) significantly reduced cell population by more than 40%. However, for all \( D_u \) as drug dosage increased, the percentage of reduced cellular growth became constant (See Figure 5). In summary, diffusion coefficients larger than 0.35, reduced the percentage of cellular growth, resulting in lower inhibitory concentration curve percentage values. While all \( D_u \) in the two-dimensional model, none of the IC\(_{50}\) curves reach 50%. That is, the diffusion coefficients \( (D_u) \) smaller than 0.1 in the two-dimensional model did not ever reduce cellular growth by 50%. While the diffusion coefficients smaller than 0.75 in the three-dimensional model did not reduce cellular growth by 50%, we see that the IC\(_{50}\) curves became constant.
## CHARTS AND FIGURES

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Terms</th>
<th>Initial Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_u$</td>
<td>diffusion coefficient</td>
<td>0.01-0.90</td>
</tr>
<tr>
<td>$\rho_u$</td>
<td>drug uptake</td>
<td>0.01-50</td>
</tr>
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<td>$R_C$</td>
<td>cell diameter</td>
<td>5 microns (5.00e00)</td>
</tr>
<tr>
<td>$F_{spr}$</td>
<td>cell radius</td>
<td>10 microns</td>
</tr>
<tr>
<td>$t$</td>
<td>spring constant</td>
<td>1.00+E00</td>
</tr>
<tr>
<td>$F_i^{\text{viscosity}}$</td>
<td>time</td>
<td>72 hours</td>
</tr>
<tr>
<td>$\sum_{i=1}^{N} f_{i,j}$</td>
<td>mass/viscosity</td>
<td>1.00e+01 nu</td>
</tr>
<tr>
<td>2D model</td>
<td>max neighboring cells</td>
<td>N=10</td>
</tr>
<tr>
<td>3D model</td>
<td>boundary drug conditions</td>
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</tr>
<tr>
<td>$d_u C_i^d(t)$</td>
<td>decay (cell toxicity threshold)</td>
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<tr>
<td>mg</td>
<td>micrograms per milliliter</td>
<td>drug dosage</td>
</tr>
</tbody>
</table>
Chart 1. Two-dimensional model was used to test different time parameters, minimum time $t=24$, maximum time $t=36$, and analyze the cellular growth with each respective time frame in order to set a control cell count for all future simulations.

**Two Computational Models**

Three dimensional model simulations show the diffusion gradient of the drug through the blue hues, while the cells that accumulate the drug die off (by the purple hues that turn darker and darker).

Two Dimensional Model Simulations show the direct distribution of the drug directly administered to all the cells (yellow gradient) and the cells die off (by purple hues that turn darker and darker).
Figure 1(a). Two-Dimensional Model. Computational representation of a Petri dish in which individual cells are seeded and allowed to grow and migrate (referred to as the 2D model). In the 2D model the drug is administered to the cells directly without having to permeate the border of the cells. In which diffusion occurs strongly since the cells are in a two-dimensional space (the petri dishes), thus the cells are much more spread out [8]. The progression of cells generated (cell duplication) from the initial fifty cells seeded are demonstrated in the three mini freeze frames of our simulations.
Figure 1(b). Three-Dimensional Model. Computational representation of the central cross-section through the cell spheroid (referred as 3D model). In the 3D model the drugs permeate the cells boarding the entire cluster. The cells represent a colony in which the cells cluster together. It shows the aggregation of the cells, which is the property of spheroids in which the code is designed to mimic. The progression of cell generation (aggregation from cell duplication) in the spheroid is demonstrated in the three mini freeze frames from of our simulations.

In both images, Figure 1(a) and Figure 1(b), the pink circles represent the cells, the red segments represent spring connections between neighboring cells. Note, that there are no connections if the cells are far apart. Green arrows represent the cumulative forces exerted on the cells and the direction of cell movement. The gradient of colors are supposed to illustrate the cells that reach a concentration threshold causing the cell to die from the drugs administered.
Figure 2. 2D Drug Dosage & Fixed $D_u=0.75$. IC$_{50}$ curve generated for 2D model (Petri dish setting) for a fixed diffusion. Coefficient of $D_u=0.75$, and drug dosages between 0 and 0.03.

Figure 3. 3D Drug Dosage & Fixed $D_u=0.75$. IC$_{50}$ curve generated for 3D model (cross-section through the 3D spheroid) for a fixed $D_u=0.75$ and drug dosages between 0.01 and 50.

Comparing the 2D model (Figure 2) with the 3D model (Figure 3) Drug Dosages: the graphs represent the inhibitory curves at a fixed diffusion coefficient of 0.75 for testing various drug concentration levels. The two dimensional and three dimensional curves are generated to compare and contrast the dosage levels necessary to inhibit cellular growth in relation to both models.
Comparing the 2D model (Figure 4) with the 3D model (Figure 5) Diffusion Coefficients at various drug dosages: instead of having one fixed $D_u$ for each model, different diffusion coefficients were tested to compare the drug dosages tested at generated graphs respectively.
DISCUSSION

Our results do not support our hypothesis that higher diffusion rates in both cases will yield less cellular growth with respect to higher drug concentrations. In fact, we saw that the larger diffusion coefficients paired with lower drug dosages inhibited at least half the cellular population much faster then the smaller diffusion coefficients paired with lower drug dosages. In other words, smaller IC_{50} values generated from both two-dimensional and three-dimensional inhibitory drug-dosage curves resulted from low drug concentrations that had higher diffusion rates. This gives the notion that cellular death does somewhat depend on how much and how fast diffusion occurs [2]. The smaller diffusion coefficients had very large IC_{50} curve percentages with respect to very low dosages in both models. In the two-dimensional model, as the diffusion coefficients increased, the inhibitory curve began to form a declining slope. It kept 90% of the cells at a very large dosage and continued to inhibit cellular growth by retaining more than 50% at a dosage of 10mg and lower. Similarly, in the three-dimensional model, when $D_u=0.75$, a much larger diffusion coefficient retained less than 50% of the cells when dosage was 10mg or less. Although our data does not support our prediction that larger diffusion coefficients yield more cellular growth with respect to higher drug dosages; the results do suggest that diffusion does play a part in drug effectiveness and whether cellular inhibition is achieved or not. Furthermore, since the process of diffusion is whereby materials are exchanged between a cell and its environment, then the rate of diffusion is affected by temperature, size of molecules, and the steepness of the concentration gradient [2]. Since the two-dimensional model represents cell colony growth in a two-dimensional petri dish, there is a higher concentration gradient as the cells duplicate, the diffusion amongst the cells would be affected less by the force within the cells, but more by their small environment, thus killed off more cells with very small drug dosages. However, the three-dimensional model represents a cross-section through a spheroid, which are aggregates of tumor cells without blood vessels, which retain many properties of solid tumors [1]. Hence, we must consider the fact that the three-dimensional model contains cells which are more compact and have more dense spatial structure compared to the two-dimensional model. The diffusion coefficient may have less impact with drug dosages, thus does not inhibit cellular growth as much over increased drug dosage. This may suggest the possibility of resistance over time towards a drug.

In conclusion, the parameters may seem to have intuitively obvious relationships, while in other situations there may be very weak signals in very meaningless data. However, there is a huge range of applications for our data. Our data explicitly showed that the average dosage necessary to inhibit at least 50% of cellular growth, for the three-dimensional model was two thousand times larger than the average dosage necessary in two-dimensional model. Our findings are consistent with previous comparative results in literature such like [1] that compare three-dimensional spheroid drug responses to two-dimensional cellular (petri dish setting) cellular drug response. It must be noted that a result like this could save many lives over the long run and be worth millions of dollars in profits if it results in the drug’s approval for widespread use. Hence, this brings considerable questions for future studies and goals for further experimentation: If there is a mathematical way to scale the two-dimensionally generated IC_{50} concentration to the three-dimensional case? Considering different cell types, since there are various forms of cancer, how do these diffusion coefficients change
Depending on the drug? What are the probabilities that long-term, low-level exposures to these drugs will cause other disease? To what extent does the drug diffusion in cells affect the initial genetic cellular interstitial materials? What are the probabilities of other impacts in those exposed to low doses of the drugs used? Is there any evidence of potential links between exposures at early developmental stages and health impacts later in life? How does the diffusion coefficient affect the nutritional balance within nanoparticles and cellular metabolism? Finding the way to utilize the two-dimensionally-generated IC50 value in the three-dimensional spheroid or mice experiments will help biologists to design more efficient laboratory experiments. If additional time were permitted our future goals for this study would be to build a two-dimensional model with the intent to simulate a spheroid slice infused into a diffusive medium and analyze the drug diffusion in comparison to the three-dimensional case.

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REFERENCES


In W.B. Yeats’s 1938 poem “The Gyres”, poetic form and content reflect each other and co-create a feeling of devolution as the poem progresses. Yeats’s manipulation of poetic form in “The Gyres”—particularly towards a breakdown of meter and rhyme—reflects the direction of his content, which also reflects a collapse of the world. Form and content notably coalesce in the last line of the poem, where meter and content complicate the poem’s lack of resolution. While Declan Kiberd’s description of “[a] twilit world of wavering rhythms and half-said things” appears to be characteristic of “The Gyres”, his related observation that form seems to be elevated over subject is mistaken.

In his 1996 book, Inventing Ireland: The Literature of a Modern Nation, Declan Kiberd writes that “A style, like a mood, goes fishing for a subject in the unconscious...The elevation of style over subject is possible only in that liminal, twilit world of wavering rhythms and half-said things” (307). In W.B. Yeats’s 1938 poem “The Gyres”, Kiberd’s “elevation of style over subject” is not reflected; instead, the style—manifested in poetic form—and the subject—the content—of the poem reflect each other and co-create a feeling of devolution as the poem progresses. The focus on form as a defining element of style is partially informed by Robert Beum’s 1961 essay “Yeats’s Octaves”, in which he notes that “[A] style, an idiom, is not achieved independently of a form. Yeats’s transition from minor Irish romanticism to world poetry involved the discovery of a form that suited him magnificently...especially of the ottava rima” (89). Yeats’s manipulation of poetic form in “The Gyres”—particularly towards a breakdown of meter and rhyme—reflects the direction of his content, which also reflects a collapse of the world. Form and content notably coalesce in the last line of the poem, where meter and content complicate the poem’s lack of resolution. While Kiberd’s description of “[a] twilit world of wavering rhythms and half-said things” appears to be characteristic of “The Gyres”, his observation that form seems to be elevated over subject is mistaken.

The inextricability of poetic form and poetic content is the theoretical backbone of this reading, and the formalist lens encompasses this methodology. In his 1978 essay, “Strict Form in Poetry: Would Jacob Wrestle with a Flabby Angel?”, Peter Viereck provides a formalist definition of poetry: “Poetry is better left undefined...but if a definition
be demanded at pistol point, then let us define it as: expressive form” (Viereck 221). Viereck makes the case that poetic form is the inherent basis for all poetry, including free verse—“Form-rejectors like William Carlos Williams…are often excessive formalists deep down…[W]ithout it [poetic form], they would have nothing to be formless against” (210). Viereck bases his argument that all poetry is formal in biological elements: in particular, humans’ bipedalism and our hearts’ “metric ticktock” facilitate the creation of a poetry that is highly attentive to rhythm. Viereck’s essay defends the merits of poetic formalism, and that very method is being used in this paper to describe how the meaning of Yeats’s content is contingent upon the meaning instilled by his implementation of poetic form.

Yeats’s disintegration of meter—particularly the dissolution of iambic pentameter—in “The Gyres” co-exists with his description of a crumbling world. Yeats, by most accounts, was a calculated formalist. Prosodic theorist Robert Beum, in a 1961 essay titled “Yeats’s Octaves,” discusses Yeats’s dedication to the eight-line stanza, arguing that Yeats’s “adoption of them [octaves] is clearly a striking example of the triumph of a poet’s instinct and experience in finding the form, or one of the forms, that best suits his maturing genius” (Beum 89). Of Yeats’s body of work, Beum observes that

“Yeats always held on to some element of prosodic form. Even at his most conversational or most savage[,] he never once abandoned both meter and rhyme in the same poem. His mind was distinctly of the type that works in form and then away from it. When he grew tired of the form, he could roll up his sleeves and shatter it—ever so masterfully, the mastery having been developed in working with the form” (91)

Beum acknowledges that both an adherence to form and a destruction of formal expectations and patterns are characteristic of Yeats’s formalism. Both of these modes coexist in “The Gyres,” where the iambic pentameter begins to derail at line 7—as early as the first stanza—and after a few metric deviations in the second stanza, the meter becomes particularly divergent in stanza three. Line 7 in stanza one contains the first of three trochees in the poem:

/ U U / U / U / U /
Hector is dead and there’s a light in Troy;

Two more trochees appear, both in stanza three:

/ U U / U / U / U /
Conduct and work grow coarse, and coarse
U / the soul,
...
/ U U / U U / U /
Lovers of horse and of women shall (lines 17 and 19)

This integration of the trochee at the start of each of these lines introduces the formal flux that Yeats generates throughout this poem, and breaks up the predictable iambic pentameter that is characteristic of the ottava rima. Beum addresses Yeats’s use of the trochee, and notes that “[H]e frequently substitutes trochaic meter…for the expected iambic…Here the trochaic contrast conveys the heightening of impulse” (95). Perhaps the “heightening of impulse” to which Beum refers manifests twofold. The conversational speech cadence of iambic pentameter is disrupted by a more vocally panicked trochee, heightening the tension in the speaker’s voice; this “heightening of impulse” could also indicate a
heightening of destruction in “The Gyres”, as the speaker foretells the apocalyptic degradation of his world. This destruction is epitomized by stanza three, where the iambic pentameter breaks down and becomes more irregular. The meter seems to embody Yeats's description in line 17: “Conduct and work grow coarse, and coarse the soul”. The meter here—and for the duration of stanza 3—takes on a coarseness, as it becomes more difficult to scan, and the meter becomes a reflection of the content. Kiberd’s “twilit world of wavering rhythms” is embodied in these devolutions of form—the intermittent trochees and the diversion from iambic pentameter; but, each formal deviation is paired with an instance of degradation in the poem's content, and these two elements inform each other.

Just as Yeats's metrical maneuvers interact with the content of “The Gyres”, the devolution of rhyme—particularly in stanza three—reflects the frenzy and incoherence of the final stanza. In stanza one, Yeats only features two slant rhymes: “forth” with “worth”, and “thought” with “out”. In stanza two, there are also two slant rhymes: “stain” with “gone” and “again”. The first stanza adopts an almost prophetic tone, as the speaker is foretelling the process whereby the earth breaks down (lines 1-8); the rhyme, featuring few slants, serves as an element of this tone, where the rhyme gives the speaker's prophecy an air of familiarity. In the second stanza, the speaker employs the refrain of “What matter?” (lines 9, 11, and 15). None of the slant rhymes in stanza two are present in lines where the refrain is used, creating a song-like format of alternating sounds, where the speaker continues their prophecy about the gyres. Where the ABABABCC rhyme scheme would be in stanza three, irregular rhymes have taken its place; Yeats rhymes “soul”, “shall,” and “owl”; “dear”, “sepulchre”, and “disinter”; and “run” and “again”. In particular, the lack of a rhyming couplet, which the other two stanzas employ, resists a sense of closure in the poem; this couplet embodies Kiberd's concept of “half-said things” in the content of a poem. Yeats is using the incomplete feeling generated by the un-rhyme of the last two lines in order to withhold a neat ending, a sentiment that is also reflected in these lines: “The workman, noble and saint, and all things run/On that unfashionable gyre again”. Therefore; the poem's form and the poem's content are co-creating a feeling of non-ending in “The Gyres”.

The content of the poem predicts the destruction of the speaker's world, but denies the closure of an ending; this arc begins in the first stanza, and particularly embody Kiberd's description of “half-said things”, as the speaker makes an obscure prediction about the world’s destruction:

Things thought too long can be no longer thought,
For beauty dies of beauty, worth of worth,
And ancient lineaments are blotted out. (2-4)

The speaker is obfuscating the ramifications of the world’s collapse, both by complicating the prophecy with repetition, and by creating an image of obscurity: “blotting out” the past. This obscuring of the past complicates the temporality of this poem. T.P. MacGloin touches upon this complication of setting in his 1987 essay, “Yeats’s Faltering World”, which examines Yeats's endeavor to create a poetic world that is more forgiving than his real one, and Yeats's “attempts to construct a world that might have compensated for the real loss” (MacGloin 473). Of Yeats’s temporality, he argues that “[W]hat becomes increasingly clear [in his poetry] is the lack of anything that might be construed as "the present"; he [Yeats] does not face it, regard it; he does not recognize or accept it. If he happens to brush with the
present time en passant, it is to provide an unfavorable contrast, an unequivocal condemnation” (473). This offering of an unfavorable contrast is plausible, given that the first stanza—the speaker’s prediction of destruction—is entirely in present tense and imperative mood. But the second stanza introduces “In ancient tombs I sighed, but not again;” (line 14)—the past tense—and the third stanza calls out to the future tense: “Lovers of horses and of women, shall…run/On that unfashionable gyre again” (lines 19-23). The speaker’s present is condemned, at least in the narrative sense, because the speaker is predicting and attempting to explain just how the world will be destroyed. The speaker places the present as an unfavorable contrast against the future, where they predict that “all things [will] run/On that unfashionable gyre again”. This content of the uncertain future, offered by a lack of closure, is supported by the lack of form closure—there is no rhyming couplet to close the poem. The beginning of the narrative arc of the poem takes on the tone of a prophecy, a tone which is created in part by the rhymes that appear in the stanza. As the meter devolves in the poem, the temporeality is complicated—tenses other than present tense are introduced, and complicate the speaker’s narration. This progressive devolution and destruction in the narrative content of the poem is supported and created in part by the formal elements of the poem that also reflect a disintegration.

Declan Kiberd’s claim that “The elevation of style over subject is possible only in that liminal, twilit world of wavering rhythms and half-said things” seems only to be a half-truth in relation to Yeats’s “The Gyres”, where neither style nor subject are elevated over the other; instead, the formal and contextual elements mutually support each other in a formally and thematically complex poem. Despite the poem’s joint formal and contextual effort to highlight the crumbling of the world, the last line of “The Gyres” offers a moment of complication. The penultimate line, 23, is one of the most irregular in the poem; the meter is irregular, and there are eleven syllables in the line, while all others have ten. However, the last line of the poem, line 24, returns to regular iambic pentameter:

U / U / U / U / U /
On that unfashionable gyre again.

This line thematically suggests that the end of the speaker’s world will be followed by the beginning of the next world, where destruction may be on the agenda, but not immediately. This final intertwine ment of regular meter and a prediction of another life cycle expresses how Yeats’s style and subject cannot be separated or unequally prioritized in a close reading. While Kiberd’s “wavering rhythms and half-said things” are elements that formally and thematically inform Yeats’s body of work, they are not disparate entities; Yeats’s manipulation of form and his complex subject matter are constantly informing each other, rendering them both as equally vital elements of his poetry.

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Patterns emerging in recent research on the relationship between women’s leadership styles and judgments of them by subordinates are challenging the assumption that female leaders are perceived as “unlikable” (Eagly, Makhijani & Klonsky, 1992; Williams & Tiedens, 2016). Although this phenomenon is well documented in the research on women and leadership, studies reported mixed results on which factors, such as leadership style, affect the likability of women in leadership (Eagly & Karau, 2002; Elsesser & Lever, 2011; Kaiser & Wallace, 2016). The current paper will examine which styles of leadership, if any, create a gender bias against female leaders and how much leadership style influences subordinate perceptions, negative and positive, of female leaders.

Patterns emerging in recent research on the relationship between women’s leadership styles and judgments of them by subordinates are challenging the assumption that female leaders are perceived as “unlikable” simply because they are in a leadership position. The first pattern emerging in the data is that subordinate perceptions of the likability of female leaders are related to demonstrated leadership style (Cellar, Sidle, Goudy & O’Brien, 2001; Eagly et al., 1992). The second pattern reveals that in the case of subordinates perceiving a female leader as “unlikable,” it is usually found in laboratory settings with hypothetical bosses (Elsesser & Lever, 2011) or real female bosses who display dominant and forceful leadership styles (Kaiser & Wallace, 2016; Williams & Tiedens, 2016). Many “flare ups” of sexism occur when a woman applies certain leadership styles in the workplace (Eagly et al., 1992). The focus of this paper will be a review of the literature on the role of gender on assumed leadership styles for women, the styles of leadership women actually use, and how these styles affect subordinate perceptions.

ASSUMED LEADERSHIP STYLES ACCORDING TO ROLE CONGRUITY THEORY

Gender is socially constructed and defines the masculine and feminine behaviors that should be exhibited by men and women (Eagly & Karau, 2002). Gender norms are prescriptive, and when
gender roles are violated, there are assumed social consequences (Eagly & Karau, 2002). Eagly and Karau (2002) apply Role Congruity Theory to explain bias against women, and men, who deviate from socially ascribed gender roles. According to Role Congruity Theory, social perceivers (e.g., co-workers, employees, managers) hold various stereotypes about groups of people that are incongruent with the attributes associated with certain social roles. This incongruence between stereotypes and assumed role attributes leads to prejudice (Eagly & Karau, 2002). Role Congruity Theory could also be used to determine which styles of leadership women in the corporate world could use to avoid the gender biases of role incongruity, perhaps by attempting to incorporate ascribed communal characteristics such as nurturance, gentleness, and sensitivity into their leadership style (Eagly & Karau, 2002; Elsesser & Lever, 2011). However, Kaiser and Wallace (2016) argued that in reality, corporate leaders do not, and cannot, fit common popular stereotypes of femininity if they wish to successfully lead. Not only are these ascribed characteristics for women not realistic in the corporate world, but they also may inhibit the social perceiver from favorably evaluating women in leadership roles that are thought to require characteristics such as assertiveness, dominance, ambition, and confidence (Kaiser & Wallace, 2016).

Stereotypes can be heavily impacted by, and manifested through, language. Koch, Luft, and Kruse (2005) longitudinally investigated changes in semantic connotations of 5 gender and leadership related concepts over a 20 year time-span using word clusters (e.g., man, business-woman, manager). Their results showed a progressive deviation from the study’s first wave of findings, which suggested that “leadership is male” (Koch et al., 2005, p. 34). In fact, in later waves in the study, they found that a new word cluster had formed: leadership, manager, and business-woman. Female participants contributed the most to these new, highly correlated words indicative of female leadership. The results from Koch et al. (2005) suggest that attitudes toward gender roles are evolving. Role Congruity Theory can still contribute to one’s understanding of the influence of implicit attitudes of ascribed characteristics for each gender, but as gender roles become more interchangeable for men and women, this theory may become less relevant for explaining bias in the future.

Role Congruity Theory may also explain how social perceptions of gender roles influence whether or not women take on leadership roles. Sheryl Sandberg (2013) addressed the “leadership ambition gap” in her book Lean In: Women, Work and the Will to Lead. She noted that women hold far fewer senior leadership positions than men across many domains, including the corporate world, and argued that it is not that women lack ambition in their careers, but that they do not aspire to senior leadership positions as much as men do (Sandberg, 2013). A perceived incongruity between women and senior leadership roles exists, as women are more likely to be mid-level managers. Although only 23 female CEOs are listed on the S&P 500 (Sandberg, 2013), most people have reported exposure to a mid-level female manager (Elsesser & Lever, 2011). Senior leadership positions are thought of by society to require agentic characteristics including directness, dominance, forcefulness and self-sufficiency (Eagly & Karau, 2002). Congruency often exists between men and these characteristics, which may lead them to be encouraged, and aspire, to keep advancing in their careers. Consequently, as predicted by Role Congruity Theory, women may be less likely to self-select into senior leadership tracks based on the perceived incongruence of the agentic characteristics necessary for senior leadership positions and the ascribed communal characteristics associated with women.
SUBORDINATE PERCEPTIONS OF FEMALE LEADERS WITH DOMINANT LEADERSHIP STYLES

Not only is there a gendered distribution of those in senior leadership positions, it is also the case that men and women may use different leadership styles in the workplace and these may be perceived differently. Kaiser and Wallace (2016) examined subordinate ratings of the leadership styles of 857 men and 857 women in upper level management from six different corporations. Results suggested that women were reportedly more likely to demonstrate what they defined as stereotypically masculine styles of leadership. These styles were labeled as “Forceful,” such as taking charge and demonstrating decisiveness, and “Operational,” which included behaviors such as executing initiatives and initiating structure constructs. Notably, men were more likely to use stereotypically feminine styles of leadership that are more people-oriented and less hands-on. These styles were labeled “Strategic,” such as shifting corporate environmental demands and establishing new directions, and “Enabling,” which included empowering and accommodating subordinates.

Kaiser and Wallace (2016) also examined subordinate perceptions of the suitability of leadership styles. They used the Leadership Versatility Index (LVI) for subordinate participants to rate the men and women on whether their leadership approach was “the right amount,” “too much,” or “too little.” Most subordinate participants rated men’s implementation of “Forceful” and “Operational” styles as “too little,” and women’s implementation of the “Forceful” style as “too much” and of the “Operational” style as “the right amount.” While women in upper-level management used amounts of the “Operational” styles of leadership that were judged as effective, their use of the “Forceful,” and explicitly dominant, style was perceived as “too much” (Kaiser & Wallace, 2016). A shift in management culture has led to an inconsistency between the general perception subordinates have of the skills required for a senior manager to lead, and the actual skills necessary for a senior manager to successfully lead. Corporate upper-level managers cannot depend solely on stereotypically masculine styles of management to successfully lead in many corporate environments that have become more democratic and people oriented (Kaiser & Wallace, 2016).

Male managers have cultivated the skills necessary to be considered for a promotion from utilizing the “Strategic” and “Enabling” styles, which gives them an advantage over their female counterparts. Male managers are less likely to develop strategic and enabling skills because they over-utilize the “Forceful” and “Operational” styles. Kaiser and Wallace (2016) contended that women in middle (and upper) management are viewed by their senior managers as effective “doers,” but are often overlooked as potential candidates for promotions. They are less likely to utilize the “Strategic” and “Enabling” styles of leadership that are viewed as necessary for “moving up the career ladder.” Female leaders may unknowingly focus on accomplishing goals and tasks for corporations, rather than envisioning and setting them, which may lead to them being perceived as having less potential for promotions (Kaiser & Wallace, 2016). Sheryl Sandberg (2013) and Kaiser and Wallace (2016) stressed the importance of women seeking mentorship and support from their superiors to gain the knowledge and to develop the skills necessary to be viewed as a potential candidate for promotions.

However, the picture is likely much more complex and it is not clear to what extent subordinate perceptions of leadership behaviors reflect actual
leadership behaviors. “Forceful” strategies may be effective in certain environments with subordinates whose personalities are more authoritarian, rather than with subordinates whose personalities are more democratic. Nor is it clear whether the level of institutional support is proportional for male and female leaders to enable them to successfully enact the same leadership behaviors with subordinates.

While a bleak picture has been painted of subordinate judgments of women’s leadership styles, the findings of two meta-analyses on gender bias and leadership style demonstrate that the picture is incomplete without considering how “dominance” is defined. Eagly et al. (1992) reported a statistical trend in their meta-analysis that suggested subordinates do, in fact, evaluate female leaders slightly more negatively than their male counterparts. This slight difference was also present in a recent meta-analysis by Williams and Tiedens (2016), who found similar mixed results in their literature review. Some findings from this study suggest that the leadership style of women is more explicitly dominant than men and that gender bias was found only against female leaders who displayed explicitly dominant behavior (e.g., direct demands, assertiveness) in their leadership style (Williams & Tiedens, 2016).

One notable finding from Williams and Tiedens (2016) was that gender bias did not exist when female leaders utilized subtle and implicit (e.g., eye contact) forms of dominance (Williams & Tiedens, 2016). Explicit forms of dominance led to an overall slight gender bias and prejudice against female leaders, likely because they deviated from ascribed communal and feminine characteristics (Williams & Tiedens, 2016). Since explicit forms of dominance (i.e., assertiveness, decisiveness, making demands) are associated with masculinity, women are more likely to face negative evaluations when they engage in these behaviors (Kaiser & Wallace, 2016; Williams & Tiedens, 2016). Such findings may suggest that female leaders choose to use implicit forms of dominance to lead in order to still be evaluated favorably by their subordinates, but when explicit forms of dominance are used to lead, a slight gender bias toward these female leaders can be expected.

Women are using dominant leadership styles even when there are negative consequences associated with a dominant leadership style. Research has not yet explained why women leaders choose a dominant leadership style. One hypothesis is that female leaders use dominant leadership styles because they are under disproportionate pressures at work to be efficient and find a balance with demanding home lives. For example, many women in the workforce are looking for flexibility in their jobs and feel they need to find a “work-life balance” because women, more so than men, feel the societal pressure to “have and do it all” (Sandberg, 2013). Self-selection is also occurring, wherein mid-level female managers may be less likely to actively seek a promotion because of the more rigid work schedules of senior-level positions. Much of the research on women’s leadership styles focuses on which styles are being utilized and how they are shaping subordinate perceptions, but more research is needed on the factors that influence women’s leadership style choice. For example, female leaders may be more likely to face challenges from subordinates and use forceful leadership in response. Research should investigate factors influencing women’s leadership style choices, including women leader’s needs (e.g., desire for flexibility), corporate environments (e.g., employees who are less responsive to women leaders), and societal motivators (e.g., “have and do it all”) that cause women to utilize styles of leadership that may be effective in mid-level leadership but may not get them promoted to senior-level positions.
WARMTH-COMPETENCE PERCEPTIONS OF HYPOTHETICAL VERSUS ACTUAL FEMALE LEADERS

The warmth-competence theory may shed light on the reasons female leaders with explicit, dominant styles of leadership are perceived more negatively. The warmth-competence theory is a development of social cognition studies that distinguishes people’s impressions of others based on “liking” and “respecting” (Fiske, Cuddy & Glick, 2007). The two dimensions, warmth (i.e., likability, trustworthiness) and competence (i.e., respect, efficiency), are driving forces that influence people’s initial judgments of others (Fiske et al., 2007). The evidence from social cognition studies strongly suggests that warmth and competence account for approximately 80% of the variance in perceptions of individuals and groups in everyday social behaviors (Fiske et al., 2007). In other words, the dimensions of warmth and competence are crucial to the impressions people have of others. People do not always like the people they respect, nor do they always respect the people they like. The warmth-competence theory could strongly influence the initial reactions subordinates have toward female managers and leaders, both hypothetical and actual. The warmth dimension is a strong predictor of whether the initial impression of an individual or group is positive or negative; whereas the competence dimension is a predictor of how positive or negative the impression is perceived (Fiske et al., 2007). An individual must display a narrow range of sociable behaviors (e.g., Role Congruity Theory) that lead to a presumption of warmth. Female leaders that display explicit dominant leadership styles are presumed to be competent, but not warm because their behavior is outside of the narrow range of social characteristics that are ascribed to women. Warmth-competence theory may also be used to explain why wealthy people, Asian people, Jewish people, and female professionals are assumed to possess competence, but are perceived with lower levels of warmth which brings their intentions under suspicion by social perceivers (e.g., colleagues, peer groups) (Fiske et al., 2007).

Research that utilizes lab experiments to simulate situations and hypothetical leader behavior may give an incomplete picture in testing reactions to hypotheticals because these reactions do not solicit direct consequences for harsh subordinate judgments (Camerer & Mobbs, 2016). For example, a negative perception of a hypothetical manager does not affect a subordinate’s daily affect or behavior because the hypothetical leader is fictitious. The warmth of a hypothetical manager or boss may be lower, or perceived as lower, than an actual manager or boss that a subordinate interacts with daily and may come to know on a more personal basis. An affective and physical distance between the subordinate and the hypothetical manager is produced in laboratory settings and ignores the difference in neural activity in the brain during decisions in laboratory experiments versus real life situations (Camerer & Mobbs, 2016). Hypothetical and actual managers may not elicit equivalent reactions from subordinates because of the difference in the intensity of neural activity in the brain (Camerer & Mobbs, 2016). For instance, a hypothetical manager’s behavior may not elicit negative (or positive) perceptions from a subordinate observing this behavior from an “outside” perspective, but when that subordinate’s actual manager demonstrates those same behaviors, neural intensity will increase. Consequently, relying on reactions and perceptions from subordinates “observing” a hypothetical boss may give a misleading picture of what shapes subordinate attitudes because neural activity is different for hypothetical
and actual decisions and reactions (Camerer & Mobbs, 2016).

An excellent hypothetical example of an assertive and ambitious woman being perceived negatively is the famous Heidi/Howard study (McGinn & Tempest, 2009). Students read a case study of real life entrepreneur, Heidi Roizen, but half of the students read about “Heidi” and half about “Howard.” Ratings of Heidi and Howard’s competence were equivalent, but their perceived likability was not. The participants rated Heidi unlikable and “out for herself,” while they rated Howard “a great guy you would want to work for.” Sandberg (2013) argued that negative perception is based on the view that assertive women are overbearing and “bossy.” Sandberg’s argument is consistent with the warmth-competence theory. Warmth assessments are primary and carry more weight in determining a person’s reaction to an individual’s behavior (Fiske et al., 2007). Consequently, Heidi’s behavior was viewed as suspicious, and possibly threatening. Her behavior was counter-stereotypical and therefore did not elicit trustworthiness from the warmth dimension. Howard was initially perceived as warm (e.g., trustworthy, likable) because his behavior was congruent with the stereotypes of ambitious, assertive and confident male entrepreneurs. Therefore, it was natural for participants to view a warm and successful male entrepreneur as competent as well.

PERCEPTION OF LEADERSHIP STYLE SHAPED BY SUBORDINATE “AGREEABLENESS”

A woman’s leadership style affects the way she is perceived by her subordinates, but there are other factors besides Role Congruity Theory that influence subordinate perceptions of leadership style. Cellar et al. (2001) examined both leaders and subordinates. They examined the personality dimension of “Agreeableness” from the Five Factor Model because they were curious about how a subordinate’s level of “Agreeableness” affected perceptions of men and women who used an autocratic style of leadership versus a democratic style of leadership. Cellar et al. (2001) found that participants who scored high in agreeableness favored democratic leaders, with gender not being an instrumental factor in favorability. Participants who scored low in agreeableness favored autocratic leaders, again, with gender not being an instrumental factor in favorability. The researchers suggested that their findings could be a result of those with authoritarian personality styles valuing authoritarian attributes that are associated with “strong” leaders, regardless of the leader’s sex (Cellar et al., 2001). These findings need to be empirically supported with future research, but they create a foundation for research that may show the effect of subordinate personalities on perception of leadership styles for men and women. Whether negative subordinate perceptions of dominant female leadership styles are determined based on varying circumstances, fields, or the degree to which female leaders actually utilize dominant leadership styles is unclear (Williams & Tiedens, 2016). Varying leadership styles may be called for in each field to lead subordinates with differentially distributed personalities. Because corporate managers and leaders need to develop certain strategic skills to be successful at envisioning and accomplishing company goals, it may also be necessary for corporate managers and leaders to acquire other sets of skills from different/multiple leadership styles to successfully lead their subordinates under varying conditions.
LIMITATIONS WITHIN THE LITERATURE AND FUTURE DIRECTIONS

The leadership research literature has made progress in determining whether various factors, in isolation, impact perceptions of female leaders. An important next step is the refinement of existing theories by focusing on the combination of variables that likely play a role in shaping subordinate perceptions of a female leader’s chosen leadership style. Although Role Congruity Theory may partly explain the implicit bias female leaders face from subordinates, it is necessary to simultaneously consider leadership style, method for examining leadership (actual or hypothetical), as well as personality characteristics of subordinates, in order to gain a full and accurate understanding of subordinate perceptions of female leaders. Examining any of these variables in isolation may be misleading, or at best, may offer an incomplete picture.

One limitation of studies that use unique indexes such as Kaiser and Wallace’s (2016) Leadership Versatility Index (LVI) is that it is difficult to compare their results to other findings because the measures and methods being used are not equivalent. If tools such as the LVI were used as part of the foundation for analytic approaches in future leadership gender studies, more consistent and generalizable findings may be reported.

CONCLUSION: HEADING IN THE DIRECTION OF A NEW NARRATIVE

Although much of the research presents mixed results and conclusions on how women’s leadership style affects the perceptions of their subordinates, there is hope of moving toward a new narrative. One of the most researched factors that is contributing to the perception of female leaders is leadership style. A workplace environment that is more oriented toward social and communicative skills has become a new cultural norm for corporations (Koch et al., 2005). Such changes could be advantageous for women in leadership as they are socialized to be more communicative in their relations with others.
The overall initial perception of their level of warmth may increase to meet the high level of competency that subordinates view in them. The way in which women communicate through their leadership style may affect them positively if they use more democratic and “Strategic” styles of leadership (Kaiser & Wallace, 2016), but subordinate personalities may moderate or mediate this effect (Cellar et al., 2001). Both women and men will have to adapt their styles of leadership to the rapidly changing corporate environments that have new and challenging demands for leaders.

REFERENCES


As cultural diversity increases across the United States, it is important to explore how it impacts various facets of our society. The U.S. Census (2015) reported that by 2044, the current minority racial and ethnic groups will become the majority in the United States. In addition, by 2020, approximately half of all children in the country will have at least one minority parent (U.S. Census, 2015), which suggests that growth in diversity is happening even sooner than one may think. An area where it is especially important to study these changes is in the mental health and counseling services field. Diversity of cultures has received more attention in the therapy literature over the past several years, and its importance in the field will only continue to grow as the country experiences a burgeoning of different backgrounds. Studies demonstrate that minorities are more likely than White Americans to dropout and underutilize mental health services in the United States (Casas et al., 2002 as cited in Vasquez, 2007; Wintersteen, Mensinger, & Diamond, 2005). This leads us to question and investigate the reasoning behind these imbalances in mental health services.

One way to explain this issue is to look at the elements of the mental health services itself, particularly the relationship between the therapist and client. In the counseling setting, the therapeutic alliance refers to the bond between a therapist and a client and the manner in which they work collaboratively and effectively (Asnaani & Hofmann,
Furthermore, the formation of a strong alliance in the beginning stages of therapy has been directly related to positive outcomes (Horvath, Del Re, Fluckiger, & Symonds, 2011). This strong relation between the alliance and outcomes in therapy can be used to assess the therapeutic relationship in diverse therapist-client dyads. This study examined the therapeutic alliance and how racial and ethnic differences and similarities between therapists and clients can impact this crucial aspect of therapy.

**MULTICULTURAL COMPETENCE**

Multicultural competence has received increased attention in the education of prospective therapists and counselors. Mental health counselors and psychotherapists are expected to take on cases “within the boundaries of their competence, based on their education, training, [and] supervised experience” (American Counseling Association, 2014). Therefore, it is important for therapists to feel comfortable enough in their abilities to be able to effectively provide the treatment necessary for the client. Cultural competency refers to the ability of a therapist to understand, handle, and provide proper therapeutic treatment to a client of a culture different from his or her own (DeAngelis, 2015). Not only is conducting culturally sensitive therapy a standard according to the American Counseling Association, but it is also integral for positive and successful therapeutic outcomes (DeAngelis, 2015). It is critical for mental health providers to be both culturally aware and sensitive when addressing a client of either the same or different cultural background in order to provide the best possible client-centered treatment to improve overall well-being.

It has been reported that minority college students do not use university counseling centers and mental health services as much as their White counterparts (Brinson & Kottler, 1995 as cited in Constantine, 2002). This could be due to the negative perception or stigma associated with mental health treatment that is present among their culture or perhaps unfamiliarity with the topic (Constantine, 2002). Therefore, it is of significant value that therapists possess multicultural competence in order to best deal with issues of minority clients in a culturally appropriate way. The client’s perception of a therapist’s multicultural competence can reveal important information regarding their views of therapy and how their cultural identity is dealt with in therapy. Constantine (2002) reported that the clients’ perception of their therapists’ overall competence and multicultural competence predicted their satisfaction ratings of therapy. This suggests that the overall competence of a therapist, which includes an effective working alliance, can contribute to the effectiveness of therapy in minority clients.

It is important to consider the cultural values and traditions of a client when it comes to providing mental health services. For instance, in Latin-American culture, there tends to be more collectivistic and familial perspectives, whereas Americans tend to be more individualistic and independent. These differences in perspectives can be the cause of the underutilization and negative perception toward counseling and mental health services among Latino Americans in the United States (Peluso, Miranda, Firpo-Jimenez, & Pham, 2010). While it may be seen as more common for an American to seek counseling, Latinos may be expected to use their family or core social groups for support (Carter, Yeh, & Mazulla, 2008 as cited in Peluso et al., 2010). Being able to recognize this cultural difference can ensure that a therapist is providing culturally sensitive treatment that is most appropriate for his or her client.
THE THERAPEUTIC ALLIANCE

The therapeutic alliance is a significant part of the overall predictors of successful outcomes in therapy (Horvath et al., 2011). The therapeutic alliance is defined as the bond between a therapist and a client and the ability for them to work collaboratively and effectively in therapy (Asnaani & Hofmann, 2012). The therapeutic relationship is a part of the common factors theory that explains the most important factors for effectiveness in therapy (Horvath et al., 2011). The current study incorporates the common factors theory into the investigation of how the therapeutic alliance factor interacts with multicultural competence in counseling to produce effective therapeutic outcomes. The strong relationship between the alliance and therapeutic outcomes is important to consider when analyzing the therapeutic alliance. The formation of a strong alliance in the beginning stages of therapy is directly related to positive outcomes (Horvath et al., 2011). The underutilization and high dropout rates in mental health services among minorities is an issue that must be further examined. There may be many possible explanations for this finding, with one of them being that clients of racial and ethnic minorities do not have a strong alliance with their therapist (Vazquez, 2007).

RACE, ETHNICITY, AND THE THERAPEUTIC ALLIANCE

It is important to know if differences in cross-cultural counseling or therapy are even acknowledged in order to better understand the role that these differences play in the overall therapeutic outcomes. It is speculated that these discrepancies could be caused by inadequacy in considering various differences among the therapist and client, including but not limited to cultural awareness, cultural knowledge, and cultural presence in development (Maxie, Arnold, & Stephenson, 2006). Maxie et al. (2006) examined whether ethnic and racial variations between therapists and clients are discussed in the therapeutic setting. Out of the 689 psychologists surveyed in the study, nearly 85% of them stated that they had addressed cultural differences between themselves and their clients at least once in the past two years. However, despite this high percentage, on average, the therapists reported that they discussed these cultural differences in only approximately 43% of their total experiences with culturally dissimilar clients.

A study by Chang and Berk (2009) assessed the clients’ perceptions of cross-racial therapy regarding the specific factors of the relationship that predicted satisfactory and unsatisfactory therapeutic experiences. In the study, 16 clients from racial or ethnic minority groups were in therapy with a White therapist, and the overall satisfaction of each client was recorded. The clients in cross-racial therapy who reported being satisfied, were shown to believe that the therapist focused on the client’s primary needs and helped in achieving goals. This ties in directly with the therapeutic alliance, which emphasizes the mutual agreement of goals created for the client (Chang & Berk, 2009).

Wintersteen et al. (2005) explored the differences between race and gender among therapists and clients and the relationship with the therapeutic alliance, particularly among adolescent patients. They reported that clients who had a therapist of the same race, stayed in therapy for a longer period of time. The results showed that 55% of racially different therapist-client dyads completed at least two-thirds of the treatment, while 79% of the dyads with the same race completed that same amount of treatment (Wintersteen et al., 2005). They also found
that Caucasian therapists rated their working alliance with clients of the same race higher than those of a different race. In addition, minority therapists reported a higher therapeutic alliance with clients with minority backgrounds than with Caucasian clients. However, overall, the ratings of the clients were not significantly different for racially similar or different therapists. These results demonstrated the opportunities for improvement in multicultural competent counseling due to some of the variation found among similar or different backgrounds within therapist-client dyads.

This purpose of this literature review was to investigate previous studies about racial and ethnic differences in therapists and clients, specifically in the context of the therapeutic alliance. This study combines the concepts of multicultural competence and the therapeutic alliance in counseling to evaluate their interaction. Although researchers have previously conducted studies into cross-cultural therapy or the alliance, there have not been many studies that provide a comprehensive look at these two important parts of counseling, specifically in the university setting. For example, although the study from Wintersteen et al. (2005) examined the effects of racial differences on the therapeutic alliance, there are limitations that do not reveal the whole picture. That study focused on adolescents in substance abuse treatment, while the present study looked at college students at a university counseling center. This current study aimed to amass the important points presented in the literature and focus on certain aspects that will be useful in attempting to answer the original research question.

The purpose of the current study was to investigate any significant effects that differences or similarities in therapist-client racial and ethnic backgrounds may have on the therapeutic alliance. The current research attempted to fill the gap in the literature regarding the influences that racial and ethnic matching have on the therapeutic alliance, specifically among college students seeking mental health services at a university counseling center. The results of the research can be used to show the importance of multicultural competence in counseling relationships in order to provide the best outcomes for culturally diverse clients. It was hypothesized that clients seeing therapists with a similar racial and ethnic background to their own will rate the alliance significantly higher than clients who have a therapist with a different background. Additionally, therapists with clients from a different background will rate the alliance significantly lower, while therapists with clients who share similar racial and ethnic backgrounds will rate the alliance higher.

**METHOD**

**Participants**

This study involved participants from the Counseling and Psychological Services Center from a public university in South Florida. There was a total of 48 participants; Forty-one of the participants (10 males, 31 females) were clients and seven of the participants (2 males, 5 females) were therapists. Both therapists and clients consented to participate in research studies. The participants were chosen because their demographic data along with instrument data for both therapist and client were available to the researchers. The ages of the client participants ranged from 17 to 34 years with the average age of the client population being 22.05 years. The racial and ethnic backgrounds of the client population sample included: 24 identified as Caucasian (58.5%), eight identified as Latin American/
Hispanic (19.5%), four identified as Caribbean (9.8%), three identified as African American (7.3%), one client identified as Asian American (2.4%), and one client identified as Biracial (2.4%). The racial and ethnic backgrounds of the therapist population sample include: six Caucasian therapists (85.7%) and one Latin American therapist (14.3%).

**Materials**

This study used a self-report assessment, the Working Alliance Inventory Short form (WAI-S), as a form of measurement of the alliance for both therapists and clients. Horvath, who has shown the instrument’s validity and reliability, developed the WAI (Horvath & Greenberg, 1989). The WAI-S consists of a 12-item measure to assess for bond, goals, and tasks (4 items each) in the therapeutic alliance. The goals portion refers to a mutual determination and agreement of the goals set in therapy; tasks refer to the manner in which the client and therapist will work in order to achieve the goals; and bond refers to the connection between both people. Two separate versions of the instrument were given to the appropriate party: WAI-T for therapists and WAI-C for clients. Participants were asked to respond to each statement regarding how they feel about his or her therapist or client. An example of an item on the client version measuring bond states, “I feel that [therapist name] appreciates me.” An item for therapists measuring goals states, “We are working towards mutually agreed upon goals,” and an item for clients measuring tasks states, “We agree on what is important for me to work on.” For each of the 12 items, the participant is asked to rate the frequency and accuracy of the statement in a 7-point scale ranging from 1 (never) to 7 (always). The instructions ask the participant to work at a quick pace in order to ensure that the responses reflect the first impressions of the participants.

**Procedure**

The clinician participants of the study were informed about the nature of the research and were given the opportunity to accept or decline participation. The client participants were also given a form stating the intentions of the research studies in the Alliance Lab prior to their initial visit. During that time, they decided to either accept or decline participation in the study. Following the completion of the first therapy session, the client and therapist were given the WAI-S and asked to fill it out based on that first session. The instruments were filled out privately, without the presence of the other person in order to prevent any influences on the responses. The participants were asked to place the completed WAI-S in an envelope and turn it into a staff member. Both the therapists and clients were made aware that the other individual would not have access to their responses in order to ensure honesty in the answers. The envelopes with the WAI-S data were then given to the researchers to evaluate the total score and the individual scores for the subscales. The independent variable of this study is racial and ethnic background, specifically the two levels being whether therapists and clients had similar or different racial and ethnic backgrounds. The other independent variable is gender (male and female). The dependent variables are the self-report total scores (out of 84) of the WAI-S for both the therapists and clients, including the scores of the three subscales (bond, goals, tasks).

**RESULTS**

A one-way independent analysis of variance (ANOVA) was conducted to evaluate the hypothesis that both therapist and client dyads (N=41) with similar racial and ethnic backgrounds would rate the therapeutic alliance higher, whereas therapists and clients with different backgrounds would rate the
alliance lower. This statistical analysis was chosen in order to determine the mean differences between groups on WAI scores for therapists and clients. The test for the therapists’ WAI total score was not significant, $F(1,39) = 0.16, p=0.69$. There was no significant difference in the therapists’ WAI total score for clients of a similar background ($M=66.75, SD=7.96$) or clients of a different background ($M=67.71, SD=7.54$), as shown in Table 1. Additionally, the test for the clients’ WAI total score was also not significant $F(1,39) = 0.72, p=0.40$. There was no significant difference in the clients’ WAI total score for those who had therapists of a similar background ($M=70.05, SD=10.05$) or therapists of a different background ($M=72.57, SD=8.91$), as seen in Table 2. There were no significant differences in the scores for each of the three subscales of the therapeutic alliance for either the therapists or clients. The results suggest that in therapist-client relationships, the similarity or difference in racial and ethnic background of the other person does not play a significant role in how either the therapist or client rate the therapeutic alliance.

**DISCUSSION**

Overall, the results of the study suggest that similarity or difference in racial and ethnic backgrounds do not significantly affect the therapeutic alliance between therapists and clients. Contrary to the original hypothesis, the findings show that therapists did not report any significant differences in the total score of the therapeutic alliance between racially and ethnically similar or different clients. Additionally, clients did not show any significant differences in their measure of the total score of therapeutic alliance with therapists of either similar or different backgrounds. However, the results did reveal that male therapists tend to rate the total score and tasks subscale for the therapeutic alliance higher than female therapists.

Post hoc analyses also looked for any effects that the gender of the therapist or client had on their ratings of the WAI. The normality assumption for parametric tests was validated, so the Mann-Whitney U test, a nonparametric analysis, was conducted in order to adjust for the uneven sample of male and female therapists. The analyses, as seen in Table 3, indicated that the WAI therapist total score was significantly greater for male therapists ($M=71.27$) than female therapists ($M=65.77$), $U=94.00, p=0.036$. When looking at the three separate subscales of the WAI (Table 4), the Mann-Whitney U test revealed that the WAI score for the tasks subscale was significantly greater for male therapists ($M=23.91$) than female therapists ($M=21.03$), $U=73.50, p=0.007$. The bond subscale score also approached significance when comparing male therapists ($M=24.09$) and female therapists ($M=22.27$), $U=100.50, p=0.055$. These results suggest that male therapists rated the therapeutic alliance higher than their female therapist counterparts. Neither male nor female clients reported any significant differences in how they rated the total therapeutic alliance or each of the three subscales.

Although the hypotheses of study were not validated, the results reveal important findings and implications in the context of the therapeutic alliance and cross-cultural therapy. The results show that there may be more factors playing a role in multicultural counseling than merely the racial and ethnic backgrounds of the therapists or clients. The results are important in that they suggest that the general majority or minority status of the dyads may not have as strong of an effect on the alliance that specific cultural or individual differences may have (Smith, Domenech Rodriguez, & Bernal, 2011).
There may be cultural differences within groups, such as cultural identity, upbringing, and acculturation of either the therapist or client. It is also important to look at the therapist’s cultural competence and experience with counseling a client from a minority group or from a different culture than their own. These are all factors that can influence how cultural differences affect the therapeutic relationship (Smith et al., 2011).

Previous research showed that clients receiving mental health treatment from a therapist of the same race had higher retention rates (Wintersteen et al., 2005). The results from Wintersteen et al’s (2005) study are partially consistent with the results from this study. Their study found that Caucasian therapists rated their working alliance with clients of the same race higher than those of a different race, and therapists who were seeing a client from a different background rated the alliance significantly lower. However, similar to the current study, Wintersteen et al. (2005) also found that the alliance ratings of the clients were not significantly different for therapists of a similar or different race. This inconsistency may be attributed to the population sample being tested. While the first study was done with adolescent patients in substance abuse treatment, the current study used college students seeking mental health treatment through their university counseling center. It is important to note the difference in population because the clients in each setting may differ significantly in their mental health issues and other factors that can impact their experience in therapy.

The current study did find, through post hoc analyses, that male therapists tended to rate the therapeutic alliance higher than female therapists. This finding suggests that the professional role and authority figure of the therapist could be a factor in the reason that male therapists rated the alliance higher (Shonfeld-Ringel, 2001). This may be attributed to a self-favoring bias in that male therapists may believe they are performing more favorably than their female counterparts. Moreover, the results suggest that it may be important to further investigate the effects that gender differences, rather than racial or ethnic differences, may have on the alliance since significant results were found when analyzing male and female therapists (Wintersteen et al., 2005).

A limitation of the study is the small sample size used, especially the number of therapists. Future studies should attempt to increase the sample size in order to have a more accurate presentation of the population and to avoid any outliers. Additionally, there was also not a great deal of diversity in the therapist sample in this current study. The majority of the therapists identified as Caucasian, which is not an accurate portrayal of the racial and ethnic makeup of people in the United States. Therefore, a more diverse therapist population could reveal different effects in the results because clients would have a higher chance of receiving treatment from a racial or ethnic minority therapist.

Although there were not significant differences found between similar or different racial and ethnic backgrounds for therapists and clients, it is important to note that this finding was based on the measurement of the therapeutic alliance through the WAI, which is based on self-report data. Self-report assessments can produce a misrepresentation of actual thoughts and opinions. The participant may feel the need to emphasize or minimize their responses in order to prevent embarrassing or uncomfortable revelations. The participants of self-report assessments may also respond to the items in a way that is favorable to themselves, or they may respond in a way they believe they are expected to respond. It is also important to consider that the WAI was administered to both the therapist and client after just the first session, which may not be a strong indicator or
predictor of what the alliance will be like throughout the entire therapy process.

In order to address the limitations of a self-report assessment, there may be value in investigating how third-party observers rate the therapeutic alliance. By having an outside observer evaluate the relationship between therapists and clients of similar or different racial and ethnic backgrounds, we may be able to have a more objective viewpoint of the therapeutic alliance. Future research could use a form of evaluation similar to the WAI, in which an observer watches recorded videos of a therapy session and rates the alliance based on what he or she has observed. In addition, a coding system could be used to study differences in specific behaviors exhibited by therapists or clients of similar or diverse backgrounds. The findings provide future researchers with information to help uncover the reason for the underutilization and higher likelihood of dropout of minority clients in mental health services.

CONCLUSION

The current study has provided insight into the therapeutic alliance within the context of cross-cultural therapy. Although this study did not find any significant differences pertaining to the alliance and racial and ethnic differences in therapist-client dyads, the research has given direction to further research on the topic. Future research in this area of study can be useful in showing the importance of multicultural competence therapy in order to increase awareness and use of counseling services. Research investigating therapeutic factors, beyond the alliance, can be helpful in providing effective and positive mental health treatment for minority groups and diverse individuals.

REFERENCES


## APPENDIX

### Table 1

Means and Standard Deviations for WAI Therapist Total Score for therapist-client dyads of similar and different backgrounds

<table>
<thead>
<tr>
<th>Race/Ethnicity</th>
<th>Mean (Out of 84)</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same</td>
<td>66.75</td>
<td>7.960</td>
<td>20</td>
</tr>
<tr>
<td>Different</td>
<td>67.71</td>
<td>7.544</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>67.24</td>
<td>7.667</td>
<td>41</td>
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### Table 2

Means and Standard Deviations for WAI Client Total Score for therapist-client dyads of similar and different backgrounds

<table>
<thead>
<tr>
<th>Race/Ethnicity</th>
<th>Mean (Out of 84)</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same</td>
<td>70.05</td>
<td>10.050</td>
<td>20</td>
</tr>
<tr>
<td>Different</td>
<td>72.57</td>
<td>8.908</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>71.34</td>
<td>9.449</td>
<td>41</td>
</tr>
</tbody>
</table>

### Table 3

Mann-Whitney U Test for WAI Therapist Total Score looking at Therapist Sex

<table>
<thead>
<tr>
<th></th>
<th>WAITTOT</th>
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<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>94.000</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>559.000</td>
</tr>
<tr>
<td>Z</td>
<td>-2.092</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.036</td>
</tr>
<tr>
<td>Exact Sig. [2*(1-tailed Sig.)]</td>
<td>.037³</td>
</tr>
</tbody>
</table>

### Table 4

Mann-Whitney U Test for WAI Therapist Task, Bond, and Goal Scores looking at Therapist Sex

<table>
<thead>
<tr>
<th></th>
<th>WAITTASK</th>
<th>WAITBOND</th>
<th>WAITGOAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>73.500</td>
<td>100.500</td>
<td>123.500</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>538.500</td>
<td>565.500</td>
<td>588.500</td>
</tr>
<tr>
<td>Z</td>
<td>-2.712</td>
<td>-1.915</td>
<td>-1.231</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.007</td>
<td>.055</td>
<td>.218</td>
</tr>
<tr>
<td>Exact Sig. [2*(1-tailed Sig.)]</td>
<td>.006⁶</td>
<td>.057⁷</td>
<td>.226⁸</td>
</tr>
</tbody>
</table>
INTRODUCTION

Cancer is one of the leading causes of death worldwide. Various modalities are used as a cure for cancer, mainly chemotherapy, radiation therapy, surgery and immuno-therapy. In chemotherapy, the drug is injected into the patient’s body to kill tumor cells (Marios, 2014).

Different mathematical models have been developed to depict the growth of cancer cells and the effect of drugs on them. These take into account factors like the diffusion coefficients, which influence how easily drugs permeate the cell, drug resistance, which is the cell’s lack of reaction to treatment, and drug toxicity, which is the cell’s death rate after drug administration. In this study, two aspects are being considered; the first is the development of the tumor cells in the form of a spheroid, a manufactured tumor-like mass without vasculature, and the second part is the efficacy of drugs administered to the tumor cells. Multicellular spheroids are considered a surrogate for solid tumors and are commonly used to study drug delivery and tumor sensitivity to specified drugs (Marios, 2014).

The goal of this project is to develop a continuous mathematical model to investigate how to use dose response curves to control the growth of solid tumors. Dose response curves show the relationship between the drug dosage and the change in tumor size. To do this, we graph dose response curves for...
various drug efficacy rates to find the IC$_{50}$ curve which displays the ideal balance between effectively killing the tumor cells and reducing unintentional damage to the surrounding healthy tissue. The IC$_{50}$ concentration is the standard measure of the drug dose needed to inhibit the growth of the tumor cell population by half (Friedrich, 2009). Our control case is the tumor growth model without any drugs. We use this to see the total cell growth possible in 3 days. Then, the cell growth with varying drug efficacy rates will be graphed against the total cell growth (without drugs) in order to find the dose response curves. We chose 3 days as the max time because our industrial partner, The Moffitt Cancer Center of Tampa, used this time constraint for their research. For our study, we simulate multicellular spheroids, which are the classic approach for 3D cell culturing. Throughout the past three decades, multiple article reviews have highlighted the potential of this model system in cancer research and treatment (Wientjesa, 2014). Early investigations in the 1970s not only triggered the study of basic biological mechanisms in multicellular tumor spheroids (MCTS), such as the regulation of tumor cell proliferation, differentiation and cell death processes, but also initiated the progressive entry of the MCTS model into various new fields of therapeutic interest (Friedrich, 2009).

In fact, tumor cells grown as 3D structures can acquire clinically relevant multicellular resistance to apoptosis-inducing drugs that may mimic the chemoresistance found in solid tumors (Friedrich, 2009). Spheroids are aggregates of tumor cells without blood vessels, retaining many properties of solid tumors (e.g., multicellular structures, extracellular matrix, tight junctions between cells, gradients of nutrient and oxygen concentrations, and heterogeneous cell proliferation rate) (Gao, 2013). The absence of vasculature in spheroids ascertains that the transport was due to diffusion and not convection. This is important because our model is set up for diffusion. If needed, the convection terms can be added in at a later date. The model we consider here is the simplest possible model of a spatially structured multicellular tumor spheroid.

**DEVELOPMENT OF MODEL**

![Figure 1. Tumor radius and flux of drug on the boundary](image)

**Tumor Growth**

There are two models commonly used to mimic spheroids, the Logistic and Gompertz models. When creating a spherical 3D model, we first looked at the logistic growth, \( \lambda T(1 - \frac{T}{T_{\text{max}}} ) \). According to Nguimkeu, a parameter significance test based on linear regression can determine which
model is more accurate in a given circumstance. For our purposes, we chose the linear model and simplified it to be defined in a single region sphere of radius 0 to $R$, where $R$ is the maximum radius at $t=72$ hours. Later, our simple single region model can be adapted to more accurately reflect a real tumor, with three regions of cells (a dying cell core, a dormant layer, and a layer of growing cells). This is more accurate than the Gompertz model, because a typical tumor spheroid has three phases to its growth (Murray, 2002). The first is an exponential phase, then a linear phase with a constant growth rate, which later transitions into a declining growth rate (Goodman, 2008). As time progresses, cells in the core begin to die at an increasing rate. At the same time, healthy cells in the uppermost growth layer continue to increase. Since the growth rate of the necrotic core is greater than the growth rate of the proliferating top layer, the overall growth rate declines. In this study, the surface plot diagrams will show the tumor composition in tumor cells per million. The cell number may be computed by integrating over the radius for the function modeling the tumor, as will be shown in section 3.5. To create the initial dose response curve, we’re looking at the volume of the tumor when it reaches the max radius ($R=72$ hours) with no drugs administered. This becomes the control case.

**Drug Diffusion in the Spheroid**

Next we’ll look at the initial conditions for the drug diffusion and the behavior of the drug on the tumor’s boundaries, $R_o$ and $R$. Let $C(r, t)$ be the drug concentration. To ensure smooth function behavior, the drug diffusion on the boundaries is constant (Yang, 2016). At the center, $R_o$, the diffusion is 0. At the outer edge, the diffusion of the drug is at a constant concentration, $C_\infty$. If one takes the limit of the equation as $r$ goes to 0, the diffusion term becomes increasingly large. Placing boundary conditions on the equation keeps the model manageable.

For the initial conditions, at radius 0, the drug concentration is $C(0, t) = C_o(0, t) = C_0$. Next we looked at the flux of the drug diffusion on the boundary and converted it to spherical coordinates which are easier to work with (Yang, 2016). This is done by thinking of $r$, the radius (where $r \in [0, R]$), in terms of

$$r = \sqrt{x^2 + y^2 + z^2} \tag{2.1}$$

and allowing $x = r \sin \phi \cos \theta$, $y = r \sin \phi \sin \theta$ and $z = r \cos \phi$. Assuming the tumor is symmetrical, the values of $\theta$ and $\phi$ will cancel each other out in this general Laplacian representation of a sphere, and reduce the equation to the first term.

$$\nabla^2 C = \frac{1}{r^2} \frac{\partial}{\partial r} (r^2 \frac{\partial C}{\partial r}) + \frac{1}{r^2 \sin \phi} \frac{\partial^2 C}{\partial \theta^2} + \frac{1}{r^2 \sin \phi} \frac{\partial}{\partial \phi} (\sin \phi \frac{\partial C}{\partial \phi}) \tag{2.2}$$

The tumor is similar to the following figure 1. Here, $d_c$ is the diffusion coefficient for the drug. In our Matlab code, we base this value on averages found in a study performed by Gao (1). We chose to use

pre-existing data since we don’t have the resources to run the month long tests needed to create spheroid cultures.
Next, we couple the drug diffusion with tumor growth to find a model that connects tumor growth and drug treatments.

Let \( T(r, t) \) be the tumor density and \( C(r, t) \) be the drug concentration. For this model, we’re looking for the effect of the drug up to 72 hours (3 days). We chose this time limit in conjunction with our industrial partner, The Moffitt Cancer Center of Tampa, Florida. The overarching purpose of this project is to find the dose response curves which are used to find the IC\(_{50}\) curve. IC\(_{50}\) is the ideal balance between effectively killing the tumor cells and reducing unintentional damage to the surrounding healthy tissue. To create the dose response curves, we graph the tumor volume generated with varying drug efficacy rates against the tumor volume with no drugs administered. From each graph, we extract the data point which is half the tumor’s total growth. Then, these points are compiled into the IC\(_{50}\) concentration graph.

**Equations**

\[
\frac{\partial T}{\partial t} = \text{diffusion rate} + \text{logistic growth rate} = \text{tumor growth without drug} \quad (3.1)
\]

\[
\frac{\partial T}{\partial t} = \frac{\partial}{\partial r} \left( r^2 \frac{\partial T}{\partial r} \right) + \lambda T \left( 1 - \frac{T}{T_\infty} \right) \quad (3.2)
\]

\[
\frac{\partial T}{\partial t} = \text{diffusion rate} + \text{logistic growth rate} - \text{drug efficacy rate} \quad (3.3)
\]

\[
\frac{\partial T}{\partial t} = \text{tumor growth with drug} \quad (3.4)
\]

\[
\frac{\partial T}{\partial t} = \frac{\partial}{\partial r} \left( r^2 \frac{\partial T}{\partial r} \right) + \lambda T \left( 1 - \frac{T}{T_\infty} \right) - aCT \quad (3.5)
\]

\[
\frac{\partial C}{\partial t} = \text{drug diffusion rate} - \text{rate of clearance} \quad (3.6)
\]

\[
\frac{\partial C}{\partial t} = \frac{d_c}{r^2} \frac{\partial}{\partial r} \left( r^2 \frac{\partial C}{\partial r} \right) - \delta C \quad (3.7)
\]

**Initial Conditions**

For the tumor: \( T(0, r) = T_0(r) = T_\ell \)

For the drug: \( C(0, r) = C_0(r) = C_0 \)

**Boundary Conditions**

For the tumor: \( \frac{\partial T}{\partial r} (0, t) = 0 \) and \( \frac{\partial T}{\partial r} (R, t) = 0 \)

For the drug: \( \frac{\partial C}{\partial r} (0, t) = 0 \) and \( C(R, t) = C_\infty \)
**Variable and Parameter Definitions**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Meaning</th>
<th>Units</th>
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<tbody>
<tr>
<td>$T(r, t)$</td>
<td>The tumor density</td>
<td>cells/mm³</td>
</tr>
<tr>
<td>$T_\infty$</td>
<td>The max tumor density</td>
<td>cells/mm³</td>
</tr>
<tr>
<td>$C(r, t)$</td>
<td>The drug concentration</td>
<td>mol/mm³</td>
</tr>
<tr>
<td>$r$</td>
<td>The radius of the tumor</td>
<td>mm</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>Growth coefficient for the logistic growth</td>
<td>1/hour</td>
</tr>
<tr>
<td>$a$</td>
<td>The killing rate due to chemotherapy</td>
<td>mm/mmol*hour</td>
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</table>

<table>
<thead>
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<th>Parameter</th>
<th>Meaning</th>
<th>Units</th>
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</thead>
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<tr>
<td>$d_T$</td>
<td>The coefficient of diffusion for tumor cells held constant at 0.5</td>
<td>mm²/hour</td>
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<tr>
<td>$d_C$</td>
<td>The coefficient of diffusion of the drug held constant at 0.5</td>
<td>mm²/hour</td>
</tr>
<tr>
<td>$\delta$</td>
<td>The rate of drug clearance held constant at 0.5</td>
<td>1/hour</td>
</tr>
</tbody>
</table>

**Max Density of Tumor, $T_\infty$**

In order to find the max tumor density, which will be used as a basis of comparison for the overall tumor growth and cell kill efficacy, the tumor growth model is simulated for $t=72$ hours. This value is then used to graph a dose response curve, which can also be computed by

$$\int_0^R T(r, 72)dr$$  \hspace{1cm} (3.8)

According to Gao (2013), the determined max tumor cell quantity is roughly 1 million cells for a tumor of radius 1mm.

**MATLAB CODE AND SIMULATION RESULTS**

**Objectives**

The objective of this primary code is to see how the tumor grows up until $t=72$ hours (3 days), then to run the simulation while varying the drug efficacy. In MatLab, the drug concentration will be held constant at 1 to reduce the amount of data to sort through. Then, we monitor the cell death volume as a fraction of the total tumor volume. This graph becomes the IC<sub>50</sub> curve after aggregating midpoints from the dose response curves. In this code, we can vary the values of $\lambda$, $a$, and $\delta$ which represent the tumor growth coefficient, the drug efficacy rate and the drug clearance rate. To generate our graphs, we run the tumor growth surface plots with varying drug efficacy rates, and hold the drug concentration $C(r, t)$ at 1 while varying the drug efficacy, $a$, from 0.1 to 1. As shown in the chart above, $d_T$, $d_C$, and $\delta$ are held constant at 0.5 in our code. To generate the
accompanying dose response curves, we chose the critical values of \( \lambda \) for which the surface plot behavior changed from tumor shrinkage to growth. Other curves can be generated by holding these critical \( \lambda \) values fixed and varying the drug concentration.

**Methods**

To solve this system of partial differential equations, we used the add-on PDEP within Matlab (Tseng, 2012). We imputed the principle pde, its boundary conditions and initial conditions, then added a graphing function that will display each change made in an iterative loop for the variable being studied. Based upon the literature listed in our references, we set arbitrary values for \( d_T \) and \( d_C \) which are equal to the average of the values found in our readings (Gao, 2013).

\[
(\lambda_i, a_i), \ i = +1 \rightarrow (\lambda_{i+1}, a_i) \rightarrow (\lambda_{i+1}, a_{i+1}), ..., \ i = +n \rightarrow (\lambda_{i+n}, a_{i+n})
\] (4.1)

These graphs will show the tumor growth and drug concentration. The graphs can be saved manually, but Matlab is capable of automatically saving and labeling the files with the appropriate code.

Another possibility with our code is to find the equation for the original tumor growth, then take the integral with respect to the radius to find the total area under the curve or the number of cells grown up to time, \( t \).

**Critical Values of \( \lambda \), the Growth Rate, for Different Efficacy Rates, \( a \)**

As the drug efficacy rate, \( a \), increases, the critical point of the growth rate, \( \lambda \), increases proportionately. This implies that as the drug is more effective, the point at which the tumor’s growth pattern changes from concave (shrinking) to convex (growing) increases as well. This is because in the absence of the drug, equation (3.2) only, the tumor grows and reaches its carrying capacity. When the tumor growth is modeled with drug treatment, equations (3.5) and (3.7), the tumor will either shrink or grow depending on the tumor growth rate, \( \lambda \), or the efficacy of the drug killing the tumor cells, \( a \). As shown in Table 4.3 and shown in Figures 2-11, there exists a critical growth rate of the tumor in which, below

<table>
<thead>
<tr>
<th>( a ) Value</th>
<th>Critical Value of ( \lambda )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a = 0.1 )</td>
<td>( \lambda \in (0.11, 0.12) )</td>
</tr>
<tr>
<td>( a = 0.2 )</td>
<td>( \lambda \in (0.23, 0.24) )</td>
</tr>
<tr>
<td>( a = 0.3 )</td>
<td>( \lambda \in (0.35, 0.36) )</td>
</tr>
<tr>
<td>( a = 0.4 )</td>
<td>( \lambda \in (0.46, 0.47) )</td>
</tr>
<tr>
<td>( a = 0.5 )</td>
<td>( \lambda \in (0.58, 0.59) )</td>
</tr>
<tr>
<td>( a = 0.6 )</td>
<td>( \lambda \in (0.70, 0.71) )</td>
</tr>
<tr>
<td>( a = 0.7 )</td>
<td>( \lambda \in (0.81, 0.82) )</td>
</tr>
<tr>
<td>( a = 0.8 )</td>
<td>( \lambda \in (0.93, 0.94) )</td>
</tr>
<tr>
<td>( a = 0.9 )</td>
<td>( \lambda \in (1.05, 1.06) )</td>
</tr>
<tr>
<td>( a = 1.0 )</td>
<td>( \lambda \in (1.17, 1.18) )</td>
</tr>
</tbody>
</table>
that, the tumor shrinks in response to drug treatment, but when the growth rate is above the critical value then the tumor does not respond to treatment. For the dose response curves which measure the tumor cell survival at different drug dosages, the point at which the tumor shrank 50% occurred at larger drug doses when $\lambda$ increased. The tumor growth surface plots with drug administered are found on page 13 in figures 2-11. For the corresponding dose curves, please refer to figures 12-21 on page 16. Each figure is labeled in increasing $\lambda$ order to facilitate comparisons.

**GRAPHS AND RESULTS**

**Tumor Growth Surface Plots With Drug for Varying Values of $\lambda$.**

- **Fig 2 - $\lambda = 0.11$, $a = 0.1$**
- **Fig 3 - $\lambda = 0.12$, $a = 0.1$**
- **Fig 4 - $\lambda = 0.35$, $a = 0.3$**
- **Fig 5 - $\lambda = 0.36$, $a = 0.3$**
Tumor Growth Surface Plots With Drug for Varying Values of \( \lambda \)

Fig 6- \( \lambda = 0.58, a = 0.5 \)

Fig 7- \( \lambda = 0.59, a = 0.5 \)

Fig 8 - \( \lambda = 0.93, a = 0.8 \)

Fig 9- \( \lambda = 0.94, a = 0.9 \)
Tumor Growth Surface Plots With Drug for Varying Values of $\lambda$.

Fig 10 - $\lambda$ =1.17, $a$ =1.0  
Fig 11 - $\lambda$ =1.18, $a$ =1.0

Figures 2-11: The following are the tumor growth surface plots for increasing drug efficacy rates. For these surface plots, the x-axis is the radius of the tumor, the y-axis is time and the z-axis is the quantity of tumor cells per million. Here drug concentration $C(r,t)$ is held fixed at 1 and we vary the drug efficacy, $a$, between 0.1 and 1 to control the drug amount administered.

The $\lambda$ values isolated display the critical points in tumor growth where behavior switches from shrinkage to growth. This is because in the absence of the drug, equation (3.2) only, the tumor grows and reaches its carrying capacity. When the tumor growth is modeled with drug treatment, equations (3.5) and (3.7), the tumor will either shrink or grow depending on the tumor growth rate, $\lambda$, or the efficacy of the drug killing the tumor cells, $a$. As shown in Table 4.3 and in the above figures, there exists a critical growth rate of the tumor in which, below that, the tumor shrinks in response to drug treatment, but when the growth rate is above the critical value, then the tumor does not respond to treatment.
Dose Response Curves for Varying Values of $\lambda$.

Fig 12 - $\lambda = 0.11$

Fig 13 - $\lambda = 0.12$

Fig 14 - $\lambda = 0.35$

Fig 15 - $\lambda = 0.36$
Dose Response Curves for Varying Values of $\lambda$

Fig 16 - $\lambda = 0.58$

Fig 17 - $\lambda = 0.59$

Fig 18 - $\lambda = 0.93$

Fig 19 - $\lambda = 0.94$
Dose Response Curves for Varying Values of $\lambda$.

Fig 20 - $\lambda = 1.17$

Fig 21 - $\lambda = 1.18$

Figures 12-21: The following are the dose response curves for the tumor growth at different drug concentrations for $\lambda \in (0.11, 1.18)$. Dose response curves show the relationship between the drug dosage and the change in tumor size. As $\lambda$, the growth rate, increases, the data point where the tumor volume is one half of the original volume occurs with greater drug dosages. This leads to the IC$_{50}$ concentration, which is the standard measure of the drug dose needed to inhibit the growth of the tumor cell population by half (Friedrich, 2009). Our control case is the tumor growth model without any drugs. We use this to establish the total cell growth possible in 3 days. Then, the cell growth with varying drug efficacy rates will be graphed against the total cell growth (without drugs) in order to find the dose response curves. These points are later aggregated to create the IC$_{50}$ curve.
CONCLUSIONS

This project allows us to study the simulated tumor growth and dose response curves for a spheroid to find the IC_{so} concentration, the ideal balance between the drug toxicity and the efficacy of drug induced cell death. This model provides a more accurate representation of drug diffusion and clearance in 3D spheroids prior to running physical experiments. This also enables us to find the rate of drug clearance, drug efficacy and tumor growth carrying capacity more efficiently. With these coupled PDEs, we can vary multiple variables like tumor radius, tumor growth, drug concentration, and diffusion at once for the continuous case. In a discrete model, each variable would need its own ordinary differential equation to model parameter behavior in individual cells, which is more complicated.

From this study, we looked at how the drug diffuses into the tumor, tumor growth, and the resultant dose response curves. In the future, this could be extended to a 3D discrete model, which allows for closer independent parameter studies.

ACKNOWLEDGEMENTS

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REFERENCES


Asian, American, and Queer

Kingsly McConnell & Kenneth Holloway

In the United States, the twentieth century gave rise to numerous social movements which inevitably intertwined with one another. During the Vietnam War, both Asian and lesbian, gay, bisexual, and transgender (LGBT) Americans mobilized to protest warfare and imperialism. Gay liberation groups were inspired by anti-war organizations, and anti-war organizations drew influence from these LGBT groups. The two minority groups combatted the labeling of their communities as sexually deviant and challenged the notion that being gay or Asian was inherently un-American. This paper addresses these overlooked movements between the Asian and LGBT communities, and it provides insight into their complex and interwoven histories. In instances where the importance of race or sexual orientation were forgotten, these movements found conflict. Overall, while their interactions have not followed a rigid protocol of unity or disunity, the two movements have gained social and political power from their intersectionality.

Queers and people of color alike must recognize that homophobia, racism, sexism, anti-Semitism, discrimination based on physical ability, anti-immigrant xenophobia, and other discriminatory isms all have the same roots. The same social dynamic created them all: the mainstream population’s ability to isolate particular groups and characterize them as unequal, apart, and unworthy. 1

In 1982, a Chinese American man named Vincent Chin was murdered because of his race. Vincent Chin was perceived to be Japanese by the perpetrator – an employee of the automobile industry who saw Japanese autoworkers as a threat. Chin’s death was a rallying moment against anti-Asian rhetoric in the U.S., and was a catalyst for a broader Asian American movement at the time. 2 Years before his demise, a unified Asian identity was already brewing in the U.S. from the elongated war: anti-war activists mobilized to protest the war in Vietnam, Laos, and Cambodia. While both the Vietnam War and Vincent Chin mobilized the community into action, there was another unique phenomenon that shaped Asian American identity in the twentieth century. This paper will argue that it was the Asian American community’s alignment with other minority groups facing human and civil rights struggles – specifically lesbian, gay, bisexual, and transgender Americans


that caused a more modern and comprehensive label of what it meant to be Asian American. Interceding moments between these two groups were complex and lacked strict hegemony, but it was in their unity and divergence that a complex and novel understanding of Asian identity emerged in the second half of the twentieth century.

Since the initial wave of Asian immigration to the United States in the 1830s understandings of racial identity have shifted dramatically. Originally, communities tended to define themselves based on ethnicity, culture, language, and civic associations. “Asian” was never used as a distinct term of self-identity, in contrast to black and whites communities in the U.S. In fact, the term “Asian American” as a racial category was not invented until 1968, when prominent historian and civil rights activist Yuji Ichioka attempted to broadly unify the community for political activism.3

In modernity, the classification of “Asian American” is unique. One of the most astounding aspects about this racial category is that it was actively chosen, formulated and utilized to advance human and civil rights in the twentieth century. To be “Asian American” was to recognize a shared immigrant (and often discriminatory) experience with other Asian ethnicities in the United States, and to unify with this identity to gain social and political power.4 The “Asian American” label was constructed by social conditions, and naturally the racial identifier has a diverse and often conflicting history. One aspect of this history that is often neglected is the connection between pro-gay and anti-war sentiments of the sixties. The Asian and lesbian, gay, bisexual, and transgender (LGBT) communities shared experiences with marginalization in the United States, and naturally the two groups interwove in their rallies for equality and representation. A rich history of intersectionality exists between the two groups, but it has not existed without conflict and animosity.

In an early example of paralleled discrimination, Asian Americans’ relationships and marriages were constructed into a “Sexualized Yellow Peril,” according to one Asian American law scholar, Stewart Chong. In the mid-nineteenth century, Chinese men were employed by railroad companies to assist in construction of the transcontinental railroad. The work was often dangerous, so railroad companies would hire young, single Chinese men; without families, they were perfect candidates for the job.5 For example, the Central Pacific Railroad hired over 12,000 Chinese workers – approximately 80% of their workforce.6 After the railroad’s completion, a population of Chinese men were left unemployed. Furthermore, the ratio of Chinese women to men was abysmal.7 These factors instilled fear in white Americans, who saw their presence threatening to their economic and job security.

In response, the country halted further Chinese immigration. Chinese Americans were labeled as “prostitutes” and as a public safety concern. Because of their “moral and sexual differences,” they were portrayed as unassimilable to American society.8 For instance, several media reports claimed that Chinese women were inherently prostitutes because of their cultural, religious, and educational upbringing. The same report implied that Chinese men do not have proper wives and children, and that they are incapable of wanting families.9 These reports also stated that Chinese women were harshly mistreated by

3 Ibid.
8 Ibid.
Chinese men and that their culture was inherently misogynistic. This disgust of sexism was supposed to contrast a perceived treatment of white American women, which was proper and just. These perceptions were institutionalized when President Ulysses S. Grant signed the Page Act of 1875, which prevented contract laborers and “prostitutes” from Asia from immigrating to the U.S.10

This anti-Chinese (and consequently, anti-perversion) hysteria would only end after World War II. The Chinese Exclusion Act was repealed, and federal government allowed thousands of Chinese women to immigrate to the U.S. through the War Brides Act (1945) and the Alien Wives Act (1946).11 Ironically, the individuals who within the last century were prostitutes and deviants became respectable wives of American soldiers returning from war. An already marginalized target was selected to bear the brunt of sexualization and aberration: the LGBT community. As discrimination against other communities was normalized, as seen with the Asian American community, the mistreatment of LGBT people was enhanced alongside it. Since gay men and lesbian women lacked social respectability, they carried on the label of promiscuity from Asian Americans. Respectability, as defined by Joshi Yuvraj, “is constituted by performative acts that align one’s behaviors with social norms that are gendered, white, middle-class and heterosexual.”12

In the 1950s, the Lavender Scare and Second Red Scare coincided. The dislike of both gay and communist individuals enhanced each movement and their respective public figures. For example, Senator Joseph McCarthy’s popularity was not only from his anti-communist hysteria but also his anti-gay rhetoric. Many supporters saw his movement as addressing two intertwined social issues: political treason and social perversion. McCarthy’s 1954 campaign matchbook demonstrated this paralleled concern: “I am with Joe McCarthy in his fight against treason and dishonor.”13 Similarly, the two ideas interceded when communists were depicted as homosexuals and vice versa. Advertisements suggested that gay individuals were blackmailed by the Russian government into becoming undercover communist agents. One newspaper described two gay defectors as “fruity fellows,” “pansies,” and “homos,” and claimed that communists were systematically using homosexual men to spy on the U.S.; this sentiment was echoed throughout the federal government, which tried to expel both gay and communist Americans from its daily functions and operations.14

In 1950, member of Congress Arthur L. Miller (R-Nev.) said on the floor of the House of Representatives, “It is a known fact that homosexuality goes back to the Orientals, long before the time of Confucius; that the Russians are strong believers in homosexuality… Perhaps if all the facts were known these same homosexuals have been used by the Communists.”15 Miller was a physician, and he appropriated his medical background to appear to be a credible source on sexual orientation.16 Notably, Miller chose the two most powerful communist nations in the twentieth century and likened them both to homosexuality.17 The relationship between the two scares is more evident in their natural comparison by supporters, but further...

10 Arnold, Anti-Immigration in the United States, 111.
11 Ibid., 112.
14 Ibid., 37; Aaron Lecklider, “Two Witch-Hunts: On (Not) Seeing Red in LGBT History,” American Communist History 14, no. 3 (2016): 244.
17 Johnston, The Lavender Scare, 36.
analysis is necessary to consider race alongside sexual orientation and political theory. Miller’s usage of “Oriental,” although still commonly used in the fifties, is racially charged and xenophobic. In claiming that “Orientals” were familiar with homosexuality, he intended to portray Asian ethnicities as perverted and immoral, even Asian Americans. During the Lavender and Second Red Scare, similar speech was prominent to disparage both gay people and communist countries, who were often Asian. This rhetoric was successful in alienating not only political and sexual minorities, but racial groups as well.

In addition, opposition to the Vietnam War was often conflated with pro-gay politics because the warfare intensified homophobic policies in the military. To enter service, men were required to not have homosexual tendencies, and individuals who admitted to being gay or appeared ‘effeminate’ were deferred. A movement existed for men to embrace their sexual identities in order to avoid the draft. In one man’s experience with dealing with the draft board, Sparrow Robinson claimed, “In order to come to terms with the draft ... I had to come to terms with [being] gay.” Proponents of gay military inclusion were quick to mention that homosexual men and women had served in all of America’s wars, even when they were unwelcomed. They also equated the government’s homophobic legislation with racist, sexist, and classist legislation; proponents saw through divisive tactics as elements of larger institutional oppression.

While some gay men saw the Vietnam War as a means to equality, such as gaining equal access to military employment and federal service, most youth “associated the military exclusively with senseless deaths in Vietnam.” This solidarity is evident in numerous LGBT organizations concentrated on the East and West Coasts. For instance, in the autumn succeeding the Stonewall Riots, a group called the Gay Liberation Theater performed their original play, “No Vietnamese Ever Called Me a Queer” at University of California, Berkeley. The play elicited a strong response in comparing the mistreatment of homosexual Americans and the suppression of “Third World revolutions.” For many radical homosexuals, embracing a taboo sexual identity also meant rebelling against the homophobic and imperialist system which fought innocents abroad in Vietnam.

Several LGBT organizations sprang up during the Vietnam War to seek justice for victims of homophobia, cissexism, racism, and imperialism. One gay liberation group, The Red Butterfly, sought an end to oppression for the LGBT community, but also for its allied members of other marginalized classes. One of their advertised leaflets read: “The Red Butterfly supports the peoples of Southeast Asia, Africa, Latin America—all oppressed people everywhere in their battles against imperialism and for socialism.” Another organization, The Gay Liberation Front (GLF), became the country’s first organization for gay liberation in the U.S. The institution’s name was inspired by the National Liberation Front of South Vietnam, a group which sought an end to the country’s involvement in Vietnam. This decision was a clear move to unite individuals against imperialism, and it was also successful in creating solidarity between the Asian and gay American communities. According to one GLF flyer, this idea of inclusion is stated explicitly: the U.S. systems of oppression denies gay people civil rights in the same way it denies it to other minorities, such as blacks

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19 Ibid., 463.
21 Suran, “Coming Out Against the War,” 465.
22 Ibid., 458, 469.
and women. As a result, gay liberation is naturally tied to the liberation of other peoples.24 According to one scholar, the group "sought, in their very name, to claim some sort of tie to the Vietnamese enemy while the war was still raging."25

In one South Californian study, several Asian Americans claimed that onlookers saw their Asian and sexual identities as two distinct concepts without a relationship. Two gay men of Asian ancestry, Steven Shum and Diep Tran, recounted that their work for the Asian LGBT community was seen as simply a “working relationship.” For example, rather than being seen as a gay Asian man, Shum is perceived as an “open-minded” Asian man who simply works alongside gay people.26 Similarly, one woman from the Philippines named Shella Aguilar found that she was characterized by her race and gender, meanwhile her gay identity was denoted and invisible to others.27 In reference to the marginalization of LGBT Asian Americans, Eric Wat claimed that:

Students don’t expect a gay man to speak about the API [Asian and Pacific Islander] community and an API man to talk about the gay community. They assume gay men are not part of the API community, but that [only heterosexual] men are part of the community.28

In his experience, his visibility as a gay Asian man is an effective method to combat heterosexism and homophobia. It is also effective in dismantling the separation of racial identity and sexual orientation.

The mislabeling of gay Asian identities in the twentieth century is evident in the tragic murder of Loc Minh Truong. In Laguna Beach, a notably gay area of Orange County, California, a Vietnamese American, Loc Minh Truong, was found lifeless. According to one witness, the man accused of attempted murder called Truong a “fag” before savagely beating him into unconsciousness.29 The incident is widely known as a homophobic (and possibly racist) hate crime. Just four years earlier, Truong escaped from Vietnam for the U.S. with his wife and daughter.30

Jeff Michael Raines, Truong’s main attacker, previously proclaimed a desire to “beat up” homosexual people, and he clearly perceived Truong to be gay. Meanwhile, Truong’s family claimed that he was not gay.31 This contrasts court records of Truong engaging in relations with other men. For example, in 1987, Truong pleaded guilty to “lewd conduct with another man” on the same exact beach. He certainly had interactions and relationships within the LGBT community, although there is little information on self-proclaimed gay identity.32

Interestingly, the family characterized the attack racially charged. About the incident, Truong’s nephew said: “Everyone is using the fact that he was in Laguna Beach at the time to accuse him of being gay. I think it had to do with his being Asian.”33 Truong’s wife claimed the perpetrators were blinded by their hatred for his race. It is possible that both homophobia and racism motivated his attackers, but instead, almost all media reports described the attack as either homophobic or racist. Truong was not portrayed as a gay Asian man; rather, he was

26 Ibid., 94.
27 Ibid.
28 Ibid., 96.
31 Ibid.
either not gay and his attackers racially motivated, or gay and his race invisible.

In response to sexual hysteria, the lesbian, gay, bisexual, and transgender community allied with several Asian American groups. Large Asian organizations took a positive stance on the controversial topic of same-sex marriage. For instance, in 1988, the Japanese American Citizens League (JACL) amended its constitution to prevent discrimination based on sexual orientation. Hawaii’s JACL then became the first chapter to officially support same-sex marriage.\(^{34}\) Asian people from California “rallied to the call from their brothers and sisters” and created a mutual understanding between Asian Americans and LGBT Americans, even though they did not have a high-profile leader to guide the movement.\(^{35}\)

In November 1994, California passed Proposition 187. This act denied certain social services to undocumented immigrants, such as public education and health care. Its passage alarmed the LGBT community because the proposition rang with similarities to anti-gay legislation. Political solidarity formed between the groups who saw a common enemy: right-wing politicians who proposed legislation to harm their respective communities. One social response to Proposition 187 was a bumper sticker that read, “Who’s next?”\(^{36}\) It was short, yet its message effective: a movement to restrict anyone’s civil liberties could come to restrict everyone’s.

Asian American scholar Ignatius Bau contended that “coalition building” was a lesson to be learned in the wake of Proposition 187.\(^{37}\) If people of color built these “coalitions,” or unified for political and social tact, the bill probably would not have passed because of increased public awareness and education. To take this idea further, Asian Americans could have reached out to other identities, such as women’s groups and religious organizations, to accumulate opposition. Most importantly, Bau stated that gay, lesbian, bisexual and transgender individuals could have been reached more successfully by the Asian American community who were against the bill.\(^{38}\)

In contrast, one moment of conflict between the two movements was centered around the 1991 Broadway play Miss Saigon. The musical is an adaptation of the infamous Madame Butterfly, but is set in Vietnam and focuses on the relationship between an American G.I. and a Vietnamese woman working at a brothel. When introduced to Broadway, there was an overwhelming negative response from the Asian American community. The musical was seen as sexist, Orientalist, and representing “a white man’s wet dream.”\(^{39}\) This is because of the stereotypic depiction of the Asian female character, Kim. She is cast as a virgin-turned-prostitute who falls in love with an American G.I., only to commit suicide because of her undying love for the G.I. The storyline was considered by some as “the same, sick love affair” Asian women were always cast into.\(^{40}\) This is not to mention that the musical also features language that describes Vietnamese people as “slits” and “greasy Chinks.”\(^{41}\)

The Lambda Legal Defense and Education Fund, which champions LGBT rights, used the performance of Miss Saigon in one of their fundraising

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\(^{34}\) Fong, “Building Alliances,” 371-3.

\(^{35}\) Ibid., 375.


\(^{37}\) Ibid., 59.

\(^{38}\) Ibid.


\(^{41}\) Yoshikawa, “The Heat Is On Miss Saigon Coalition,” 47.
events in 1991. Outside the fundraiser, nearly five hundred people of color protested the racist musical. The implication was that Miss Saigon would cost Lambda far more than a loss in revenue. Asian and Pacific Islanders (an integral part of the LGBT community) would be stereotyped, sexualized, and demeaned; they would potentially no longer be allies of Lambda.

Audre Lorde was an African American lesbian writer who rejected Lambda’s Liberty Award because of their usage of Miss Saigon. She claimed that it was an insensitive act that demonstrated a rift between white LGBT communities and communities of color. She suggested that in the future Lambda, alongside other organizations, should always ask marginalized groups: What do you think of this? Some critics of Lorde and the demonstrators went as far as to call them homophobic (since Lambda was being targeted), even though the protesters were largely gay and transgender people of color.42

The Asian and Pacific Islander activists claimed they were “no longer willing to accept the political leadership of white male dominated organizations” when those leaderships chose to ignore intersectional issues of race and gender. By Lambda using Miss Saigon, hundreds of people in the LGBT community had to mask parts of themselves that were integral to their identity, most notably, their Asian heritage.43 This moment certainly provided a rift between two groups who could have used solidarity to enhance anti-racist and anti-homophobic ethics.

It is important to note that between moments of peace, racism and homophobia continued to exist in the gay and Asian community, respectively. Asian Americans have and do face structural racism from the LGBT community. Utilizing stock stories, scholar Chong-suk Han demonstrated this pervasive issue. While the cover of gay magazines portray a diverse cast of black, Latino, and native gay and transgender men and women, there are underlying anti-Asian attitudes.44 One Asian man detailed his experiences with others in the gay community in detail: “First, there is overt belligerence: the drunk queens who shout in my face, ‘Go back to your own country’; the tag line at the end of gay personal classifieds – ‘No Fats, Femmes, or Asians’; the guy who hissed at me in the back room ‘I’m not into Asians.’”45

The subtleties of racism perpetuated by the gay community are explained by critical race theory (CRT). In this scenario, the requirement of “No Asians” is an example of the framework of racism, and the ability to pass racism off as a sexual or romantic preference is an example of individual action which perpetuates racism. Han’s study also documented the responses of white gay men to racist accusations. Generally, they were dismissive; others explained in detail their outright disapproval for the feminine appearance of all Asian men. CRT states that different systems of oppression, those other than racism, influence Asian Americans and effect their identities and experiences. Generally, scholars deny that one system of oppression is more impactful than another.46 Heterosexism and heteronormativity are two examples of these forms of subordination which influence how Asian Americans interact and identify within society; that is, Asian Americans who are gay or transgender have a different relationship to their racial identity because of their LGBT identity.

42Ibid., 50.
These movements, although separated by intensely diverse communities, have merged throughout the twentieth century during key political moments. At the same time, these moments have complicated the relationship among Asian and LGBT American communities when the complexity of their interwoven histories was forgotten. Gay organizations do not always appreciate the impact of race, and likewise, Asian organizations have at times ignored the impact of gender identity and sexual orientation. When these histories are embraced, a comprehensive and powerful movement is possible – but this is only achievable when Asian and queer Americans recognize the prevailing institutions that oppress them both.

BIBLIOGRAPHY


A new baby can be a largely joyful or stressful experience, depending on the circumstances. Government family leave policies have a great influence over these circumstance and their long-term outcomes. Developed countries all over the world are providing families with 8 to 87 weeks of paid family leave during this time, yet the U.S. is lagging behind, only offering 12 weeks of unpaid leave (Livingston, 2016). The purpose of this paper is to describe the problems with our current leave policy, the Family and Medical Leave Act, and need for paid maternity leave in the U.S. and analyze the positive short-term and long-term benefits paid leave brings to the mother, the newborn, and the companies that provide it using recent findings from the fields of psychology, medicine, epidemiology, and public policy.

In 2017, U.S. News and World Report analyzed and classified 60 countries by their wealth and national attributes (i.e., adventure, citizenship, cultural influence, entrepreneurship, heritage, business, quality of life, uniqueness, and global impact). The United States was ranked the seventh best country to live in because of its high cultural influence, entrepreneurship, and quality of life. However, it is the only industrialized country that does not endorse paid maternity leave (U.S. News and World Report, 2017). American women only have three months of unpaid maternity leave, while other countries provide financial assistance to their new mothers for several months in order for them to spend time...
bonding with their child (U.S. News and World Report, 2017). For example, in countries such as Spain, the UK, France, Italy, Ireland, Vietnam, Denmark, Serbia, Norway, and Lithuania, mothers receive over 100 days off to be with their newborn and receive between 80-100% of their pay during this time (Killian, 2011; Weller, 2016; Keating, 2015). Due to the lack of financial assistance, some mothers in the U.S. who recently have given birth are not able to stay at home with their newborns and provide their full attention during these imperative days without having negative economic repercussions. Many American mothers have to rely on the Family and Medical Leave Act (FMLA) for job security while they are away (United States Department of Labor, 2016). This is problematic because 57% of employees are women and 70% of these women are mothers (United States Department of Labor, 2015). The bulk of the evidence suggests that Paid Family Leave (PFL), which includes paid maternity leave, can be beneficial to both the child and the mother (Gholipour, 2014; Rochman, 2013; Pevzner, 2013; Ip et al., 2007). Although the family medical leave act addresses maternity leave, paternity leave, and leave necessitated by serious medical conditions, the focus of the current paper will be on maternity leave. Specifically, this paper will look at how PFL may improve the newborn's health and cognitive development as well as the mother's physical health. Paid maternity leave may also support the strengthening of the bond between the child and the mother without forcing mothers to choose between spending time with their infant and earning an income. Despite the advantages this policy may have, some argue that PFL may hurt small businesses financially. The evidence in support of and against this assertion will be reviewed.

PAID MATERNITY LEAVE BENEFITS

Research on states that offer paid maternity leave supports the idea that it benefits both the child and the mother, especially those with lower and middle class income who are often forgotten in the FMLA (Anthony, 2008; Gerstel & McGonagle, 1999). Having paid maternity leave can be beneficial for newborns as it can improve their health; for example, it grants the mother the time to go to the doctor’s office for the child’s checkups and immunizations. Research conducted by Daku, Raub, and Heymann (2012) found that mothers that stay home are 22.2% - 25.3% more likely to have their child vaccinated for measles and polio but they did not find an increase in child vaccination when the mother was not provided with paid leave. Furthermore, Rapaport (2016) found that infant mortality decreased when a parent stayed home, especially after the 1st month and in lower class families, it was found that with every additional month the mother is able to stay at home due to parental leave, the infant mortality rate decreases by 13%. Rossin (2011) also showed that leave is associated with an increase in newborn’s birth weight. Unfortunately, because paid leave is often not offered, according to MacDorman, Mathews, Mohangoo, and Zeitlin (2014), the U.S. has the highest infant mortality rate in comparison to other industrialized countries, which can be linked in part to the inability to provide infants with the health care necessary for proper early development.

Paid family leave can also help increase an infant's cognitive development. Gholipour (2014) performed a study on 87 newborn brains and concluded that their brain grows an average of 1% a day for the first 3 months and .4% in the months following. Therefore, in the first 3 months alone, a newborns brain grows by 64% (Gholipour, 2014). If a parent is available to provide cognitive stimulation
to their child during these crucial days of development, it could have long-term payoffs. An infant's development during their first months can also affect their cognitive development when they grow older. For example, a study conducted in Norway analyzing the long-term effects of paid leave, showed that mothers who took advantage of this program and were able to spend more time with their newborn, in the future that child was less likely to drop out of high school by 2.7% (Carneiro, Loken, & Salvanes, 2015). The researchers also concluded that the child was more likely to receive a higher income at age 30 by 5% (Carneiro, Loken, & Salvanes, 2015). Thus, paid maternity leave may allow the mother to take time off and later provide a stimulating environment for their child, perhaps positively affecting the newborn's cognitive development even years later.

Paid maternity leave also appears to support breastfeeding. Although there are numerous reasons why mothers may not be able to breastfeed their newborns, such as because of an infection or not enough glandular tissue to produce milk, some of the problem is undoubtedly financial. Research shows that because mothers are not getting paid when taking care of their child and have to return to work immediately, only 27% of newborns are breastfed for a year (National Center for Disease Prevention and Health Promotion, 2014). More surprisingly, 10% of one-week-old newborns are fed formula and by six months, this percentage increases to 43% (Pevzner, 2013; Rochman, 2013). Due to the time constraints imposed by work schedules, many families lack the opportunity to breastfeed their newborn, decreasing the infant's protection against infectious disease and Sudden Infant Death Syndrome by 36% (Ip et al., 2007). Furthermore, according to Stuebe (2009), infants who are not breastfed are more likely to have an increased risk for developing asthma, diabetes 1 and 2, and leukemia. Specifically, Ip et al. (2007) analyzed over 9,000 studies on the correlation of breastfeeding and children's health in different developing countries, and found that children who had been breastfed for three months showed a 27% decrease in the risk of developing asthma and a 24% decrease in the risk of developing obesity. Breast milk also produces minerals, vitamins, fats, protein, and natural antibodies that can help the newborn fight off illnesses (Martin, Ling, & Blackburn, 2016). However, because of the number of mothers who return to work after just a few weeks, breastfeeding has become almost impossible to maintain (Murtagh & Moulton, 2011). Therefore, paid maternity leave through PFL can grant mothers the time to more fully meet their child's short-term and long-term health needs, which as recently mentioned, can be beneficial to the child's health (Huang & Yang, 2015; Appelbaum & Milkman, 2011).

Breastfeeding can also be beneficial for the mother's health. When a mother breastfeeds for a year, it decreases her risks of cancer, specifically ovarian cancer by 21% and breast cancer by 28% (Ip et al., 2007). Researchers also found that mothers who breastfeed show a decrease in risk of developing cardiovascular disease as breastfeeding lowers the individual's serum lipid levels (Schwarz et al., 2009; Peters et al., 2017; Ip et al., 2007). Breastfeeding also helps the mother return to her original body weight at a quicker rate and there is a reduction in developing type 2 diabetes mellitus by around 36-57% (Gunderson et al., 2015). In addition, researchers believe that breastfeeding can decrease the risk of postpartum depression by around 50% because breastfeeding helps release oxytocin, a hormone that increases trust and empathy, playing a central role in bonding (Borra, Iacovou, Sevilla, 2015; Kim et al., 2015). Uvnas-Moberg and Prime (2013) found that women who breastfed reported higher feelings of calmness, more social interactions, and lower stress. Because of the immense benefits breastfeeding has towards both the mother and the newborn,
the American Academy of Pediatrics recommends mothers to breastfeed for at least six months (Bartick & Reinhold, 2010).

THE HISTORY OF THE FAMILY MEDICAL LEAVE ACT

In the last 30 years, there has been slow progress when it comes to establishing maternity leave policies in the United States. The first formal act that was proposed to help families with maternity leave was the Family Employment Security Act (FESA) in 1984 (Wisensale, 2001). Unfortunately, President Reagan, Congress, the U.S. Chambers of Commerce, and the National Association of Manufacturers strongly opposed the extra cost of the proposed paid maternity leave, which made it impossible to carry the act through (Wisensale, 2001). Legislation achieved a step forward in 1993 when a similar law, the Family and Medical Leave Act (FMLA) was passed. The FMLA is a policy that allows certain employers to provide their employees with unpaid leave due to medical or family reasons, without the fear of losing their jobs. Specifically, in regard to newborns, the FMLA requires companies to provide both the mother and the father with unpaid leave for up to 12 weeks per year in order to take care of their newborn, newly adopted child, or because they, or a family member, are experiencing a serious health condition (United States Department of Labor, 2016). The purpose of the FMLA is to decrease the burden on individuals by securing their job while they are away, and at the same time, not hindering companies financially (Waldfogel, 2001). Unlike the Family Employment Security Act, the FMLA does not promote leave pay for mothers, but instead, only job security while they are home (Wisensale, 2001). However, this does not guarantee the mother with the same job upon her return. The individual may receive any job that benefits the company as long as it provides the same pay and benefits as the previous job (Wisensale, 2001). However, FMLA is still an advancement towards achieving maternity leave.

DISADVANTAGES OF THE FAMILY MEDICAL LEAVE ACT

Although the FMLA is an advancement compared to the FESA, the act has numerous gaps. Research shows that because the purpose of the FMLA is to try to broadly aid all companies equally, the government is not able to have full control of the way FMLA is implemented and only establishes rules that dictates who qualifies as an “eligible” employee (Berman, 2011). Not all workers are able to qualify for this program; one has to be employed for at least 12 months in the same company and work a minimum of 1,250 hours prior to approval (The United States Department of Labor, 2017; Berman, 2011). The individual must also work at least 25 hours every week for a minimum of 50 weeks. Furthermore, the company must have more than 50 employees who work at the local company or 75 miles from the company’s location in order for employees to be eligible to benefit from FMLA (The Spitz Law Firm, 2017; United States Department of Labor, 2016).

The National Partnership for Women and Families (2016), a non-profit organization that focuses on promoting equality and fairness concerning health issues such as health care, reproductive rights, and paid leave, conducted an analysis regarding the U.S. policies and how well the government protects company employees and awarded each state with a letter grade. Specifically, this grade demonstrates how each state enforces paid and unpaid family leave and job protection while the employee is away. The grade provides a simple index of FMLA performance by state. The highest grades were
given to the states that enforced and “guarantee[d] paid family leave and pregnancy accommodation” (National Partnership for Women and Families, 2016, p. 5) and required companies to support their employees by providing job protection while mothers were on leave. In contrast, failing grades were given to the states that neglected to implement laws that could benefit and support families spending time with their newborn (National Partnership for Women and Families, 2016). Unfortunately, they found that 74% of the fifty states achieved a C or lower when it came to supporting individuals during paid/unpaid maternity leave, paid sick days, or nursing leave. Overall, 2 states received A’s, 11 states received B’s, 10 states received C’s, 15 states received D’s, and 12 states received F’s (National Partnership for Women and Families, 2016). The fact that 54% of the state governments are failing to enforce a minimum amount of support to families during their leave shows that the application of government acts such as FMLA are not as beneficial as they could be to employees (National Partnership for Women and Families, 2016). Knowing the grades of each state allows us to consider which states need more help and require attention with FMLA, and which states with higher grades could be used as a positive example. For instance, knowing that California received an “A” could allow the government to re-strategize and use California as a model and apply their tactics to states that received lower grades.

Models of more expensive and effective family leave programs can also be found in the policies of other nations, especially Europe. For example, the United Kingdom offers mothers 273 days of paid leave and 91 days of unpaid leave to spend with their newborn and to adjust to the new changes in their lives (The Huffington Post Canada, 2012). Similarly, Sweden provides mothers a year and two months, with 80% of their pay, to spend with their child (The Huffington Post Canada, 2012). Denmark, Croatia, and Norway provide mothers with their full pay for 252 days while on maternity leave and in Finland, mothers are provided with 161 days of paid leave along with a free maternity grant, which is a package the family receives that contains baby products, such as a sleeping blanket, a crib, clothes, a book, personal care items, bedding, towels, a toy, and bibs (Weller, 2016; Kela, 2017). More importantly, in Finland a mother receives financial assistance and a maternity package regardless of her current employment status (Weller, 2016). The comparison between European countries with the U.S. on maternity leave is important because it allows a deeper understanding of how the U.S. is performing on a more global level in this area.

In the U.S., the lack of governmental control over company leave policies through the FMLA allows the potential for companies to manipulate the system and decide which employees should or should not receive FMLA benefits. Since 1995, the number of companies who use the FMLA has decreased by 61.8% in only five years (Waldfogel, 2001). More specifically, according to Wen-Jui Han and Jane Waldfogel (2003), only 46% of Americans are fully protected from losing their jobs when using FMLA. Even if by law the company cannot deny an individual FMLA benefits if the employee meets the government requirements, the business can purposely delay when the individual receives the benefits and they may even ask the individual to use their paid vacation days before final approval (United States Department of Labor, 2016). The company can also delay the individual’s application by asking for a second or third opinion from different doctors or request a medical certification and can deny the application if either latter requirements does not provide enough evidence that the leave is necessary (United States Department of Labor, 2016).

As a result of this sort of company leave policy manipulation, the amount of discrimination in
the workforce towards lower income employees has increased. According to Gerstel and McGonagle (1999), women who have higher salaries and can afford to take the time off are most promising to qualify for FMLA benefits, and therefore, are more likely to spend time with their newborn. Their study showed that two-thirds of middle-class white mothers who make $50,000 or more are able to benefit from the FMLA, while a little over one-third of individuals who make $20,000 or less will receive the same benefits. Furthermore, white mothers are more likely to take leave compared to African Americans by almost 52% (Gerstel & McGonagle, 1999). For this reason, many low-income employees return to work only a couple weeks after their child is born, as they cannot afford to stay at home without pay. Furthermore, according to research conducted by Wisensale (2001), 60% of low-income individuals (individuals who make less than $30,000 a year) who qualify for FMLA benefits, do not take the 12 weeks off because of the economic burden it would bring them. In other words, the options supplied by the FMLA put many soon-to-be mothers in the position of having to choose between their financial stability and spending time with their newborn.

Additionally, due to the amount of control that companies have over granting FMLA benefits, many soon-to-be mothers have to depend on the “employers’ generosity” (Human Rights Watch, 2011, p. 2) for time off and, therefore, only around 20% of new mothers fully benefit from this act. Since one can use FMLA benefits before or after the child’s birth, businesses try to maximize the employee’s time in the company and often only allow the mother to go on maternity leave when they are no longer able to work due to their pregnancy. For example, in Alabama, an employee “must work until she is disabled as a result of pregnancy” (Employment Law Headquarters, 2012, p. 1) and even then, the organization “may require a doctor’s verification of disability,” (Employment Law Headquarters, 2012, p.1) making it very difficult for mothers to have time off while pregnant and requiring the additional time and expense of doctor visits and reports for verification. In an effort to improve this, the government implemented a tax benefit (depending on the contributed amount) to individuals that donate some of their sick days (up to 80 hours a year) to other mothers in the hopes to increase their maternity leave days (Georgia Institute of Technology, 2015). However, even though the donor can collectively give 80 hours, each recipient can only request up to 40 hours. The recipients must also be employed for at least a year and have exhausted all of their vacation and sick days, as well as provide a certification from their physician before using the donated hours (Georgia Institute of Technology, 2015). Even then, if there is a disability because of the delivery or pregnancy, the individual is ineligible to receive donated days. Lastly, if for any reason the awarded times are not used by the recipient, they cannot be returned to the donor (Georgia Institute of Technology, 2015). Therefore, even though the FMLA is a positive step toward maternity leave, the amount of control companies have over how, when, and for whom to implement the leave mandated by the act and the difficulty for those who try to receive additional leave hours can be seen as obstacles that outweigh the positive aspects of FMLA benefits.

**THE PROGRESS OF PAID MATERNITY LEAVE**

Despite some of the negative aspects regarding the FMLA policies, there has been positive progress within state legislation. One act, Paid Family Leave (PFL), was created with the hopes of helping families during their leave, including establishing paid maternity leave. There are currently four states that
benefit from PFL: California, New Jersey, Rhode Island, and New York (National Partnership for Women, 2017). As a result, 11% of Americans are able to benefit from paid maternity leave, which is an improvement (Devlin, 2015). California became the first state to institute the PFL act in 2004, allowing employees to receive 55% of their pay, but no more than $1,173 a week for six weeks (Rossin-Slater, Ruhm, & Waldfogel, 2011; State of California Employment Development Department, 2017). Research conducted by the Human Rights Watch (2011) demonstrates that Californians only pay a minimal tax of 1.1% for maternity leave, making the PFL act a highly efficient tactic to collectively create positive change. Five years later in 2008, New Jersey became the second state to have paid family leave with the passing of the New Jersey Family Leave Act (Department of Law & Public Safety Division on Civil Rights, 2008; National Partnership for Women, 2017). This act granted soon-to-be mothers 66% of their pay for a maximum of $633 a week for six weeks (National Partnership for Women, 2017). Similarly, in 2014, Rhode Island enacted the Temporary Caregiver Insurance (TCI) program where soon-to-be mothers may be provided with four weeks of partial paid leave in order to bond with their newborn (Silver, Mederer, & Djurdjevic, 2016). Individuals pay a tax of .0012% of their wage base income (the maximum amount the individual made that year collectively) and are able to receive between $72 to $736 a week, depending on their salary (Human Rights Watch, 2011; Laurence, 2017). To benefit from the TCI act, the employee has to give the company a 30 day written notice and “be out of work” (Rhode Island Department of Labor and Training, 2014, p.1) for a week before the mother can apply. Unfortunately, if an individual tries to apply before their date of leave, the application will be sent back to them. Additionally, through the Temporary Caregiver Insurance program, the mother’s job is protected while she is away, but similar to the FMLA, it does not necessarily protect her specific job; the company may ask the individual to return to a “comparable position” (Rhode Island Department of Labor and Training, 2014, p.2) as long as the company provides the same pay and benefits as before. The fourth state, New York, just recently implemented Paid Family Leave this year (2017); thus, the benefits of this policy in this state are yet to be seen but may include the individual receiving 55% of their pay for ten weeks (National Partnership for Women, 2017b).

PAID MATERNITY LEAVE OPPOSITION

Some economists and business owners are concerned with implementing Paid Family Leave in other states because of the extra cost it can bring to the government, the employee, and the company itself. Some economists argue that even though the states that do provide paid leave finance the policy through higher taxes and federal government aid, the act’s cost to companies is still very large, especially for small businesses (Costanzo, 2016). Small companies might not be able to afford this additional cost and as a result, many do not offer paid leave because of the expense to hire and train new employees during the individual’s absence. Researchers also argue that hiring new personnel and trying to find the best worker for their company is an additional time cost (Sadler, 2016). Michael Nutter, the mayor of Philadelphia, vetoed paid leave, especially paid sick leave, two years ago because it was considered too expensive for local companies. He believed that providing this benefit could cause small companies an economic and administrative burden (Brown, 2011). However, according to the National Partnership for Women and Families (2017a) “there is no evidence that businesses suffer when workers have paid leave,”
(p. 2) and they instead found that the act can benefit both the employer and the employee.

Although researchers agree that small companies are important in the equation of maternity leave, many refute the idea that companies are negatively impacted by paid maternity leave (Gault et al., 2014; Appelbaum & Milkman, 2011). Some economists have argued that even though Paid Family Leave is an additional short-term cost for the company, the overall long-term benefits may outweigh the short-term expense (Stroman et al., 2017). Specifically, proponents suggest that the act can have a positive impact on small businesses because it saves them money, time, and improves the employee’s performance and profitability upon return. According to Appelbaum and Milkman (2011), 86.9% of the companies that participated in the Paid Family Leave program demonstrated that it did not increase their overall cost, and instead, 8.8% of the companies demonstrated an increase in profit. Additionally, 91% of companies stated that the PFL act created a “positive effect” (Appelbaum & Milkman, 2011, p.5) in their company, and 88.5% of companies stated that it helped increase their business productivity. This may be because paid parental leave helps mothers feel supported and it allows them to stay in the job that they may enjoy doing, which can increase their productivity levels upon return. This also saves the companies from having to waste time and money finding, recruiting, and training new employees. Additionally, states such as California have become proactive in incorporating small businesses by expanding their PFL act to include smaller companies with 35 or more employees starting in July 2017 and companies with 20 or more employees starting in January 2018 (National Partnership for Women and Families, 2017b).

Along with focusing on the impacts of including smaller companies in PFL benefit reforms, future research should also focus on how to make the transition back to work as smooth as possible for mothers. As previously stated, companies may require mothers to commence a different role upon their return, which may make it harder for them to adjust as they are now having to accommodate to a new child, a possible new position, and responsibilities simultaneously. Different strategies and alternatives for temporarily reassigning responsibilities should be further investigated.

In order to increase the number of individuals who can benefit from Paid Family Leave, all states should be provided with funding for this act. Specifically, every company, regardless of how many employees they have, should take part in this program. Mothers should receive a minimum of 55% of their pay during these months to ensure they can provide their child with the resources they need. Yet, it is up to each state to decide if they would like to allocate the mother more than the original 55% of pay, as some of the previously mentioned states have (e.g., New Jersey). However, one of the difficulties in implementing this act is the question of how it will be funded. Future research may be able to help establish the most efficient organizational tactics for keeping PFL costs to a minimum for all parties involved.

CONCLUSION

In conclusion, even though there are gaps in the Family and Medical Leave Act, states have enacted different legislation to help address this problem and try to provide employees with Paid Family Leave. Furthermore, every year more states are following this positive progress as research demonstrates that providing employees with the benefits of PFL has numerous advantages to the mother, the child, and the company (Gault et al., 2014). For example, the District of Columbia in
Washington D.C., has recently legislated PFL which is scheduled to go into effect in July 2020 (National Partnership for Women and Families, 2017). There are also other acts that have been formed and developed to help implement more positive family leave policy progress. For example, in 2009, a new federal bill was introduced, The Family Income to Respond to Significant Transitions (FIRST) Act, that would help increase paid leave by providing $1.5 billion in grants to make it easier for soon-to-be mothers to take time off (Marrero, 2009).

Acts like the PFL and FIRST can be used as a foundation for future maternity leave reforms. Addressing these issues in a comprehensive way may improve the newborn’s health, the mother’s health, the bond between the mother and the child, and the profitability and functioning of businesses. In the end, the infants’ and mothers’ health and social benefits resulting from paid family leave may go hand in hand with corporate financial benefits.

REFERENCES


A Discussion on Synesthesia

Dakota Merchant & Sang Hong

Synesthesia is a rare condition in which different sensory modalities pair during the perceptual process. Grapheme-color is the most commonly seen type of synesthesia where a color is perceived when viewing a letter or number. For many years synesthesia was not widely researched due to the rarity of the condition, about 1 in 2000 people in the population are affected, and there not being enough tangible scientific evidence to determine whether synesthesia was real. Once researchers determined synesthesia was a real condition there was a need for tests and criteria to be developed that could be used to determine whether a person had synesthesia versus hallucinations as a byproduct of a different disorder. Current research on synesthesia has been able to show the genetics of the condition along with the many different ways synesthesia can be presented.

The Diagnostic and Statistical Manual of Mental Disorders (DSM-5, 2013) describes synesthesia as a condition where stimulation of one modality, be it sensory or cognitive, will result in an automatic experience in the other modality. The root word definition for the term synesthesia originates from Ancient Greek, which denotes “syn” as together or with and “aesthesia” as sensation, which gives a literal translation of sensations together (Robertson & Sagiv, 2005). The most common expression of synesthesia comes in the grapheme-color form of the condition which states that specific colors are perceived with certain letters and numbers (Brang, Rouw, Ramachandran & Coulson, 2011). The synesthetic perceptions can also be experienced if the synesthete were to think of and visualize the letter A, the color would then be associated with that letter as well, even though the synesthete is not directly looking at the letter.

Synesthesia has a wide range of sensory modality pairings; such as grapheme-color (i.e., letters and numbers associated with color), colored hearing (i.e., sounds produce visual images, most commonly colors), and colored time units (i.e., months, weeks, days are associated with a color), to name a few of the different sensory pairings (Marks, 1975; Robertson & Sagiv, 2005). Each of the different sensory pairings give rise to a highly individualized synesthetic experience, causing an inability for some aspects of the condition to be generalized. Therefore, only basic information such as, type of synesthesia and its unique sensory pairings can be generalized during the identification process of the condition.

The particularly interesting aspect of synesthesia and what drives research is that two completely distinct, differently processed senses can be paired together during perception. As shown by Robertson and Sagiv (2005), synesthesia is a not a condition...
that can be learned, instead it is something that is gained through development, so much so, that people who experience synesthesia say they did not know there was a problem with, or a difference in how they experienced the world with synesthesia (Robertson & Sagiv, 2005). Due to a lack of knowledge, for many years research was not conducted on how the different sensory modalities can be paired, but whether the synesthesia experiences were real, rather than hallucinatory perceptions as side effects of disorders, such as schizophrenia, or substance abuse.

The pairing of the separate senses creates a different neural mapping than is seen when a non-synesthete perceives the same stimuli. The different neural mappings of a synesthete and a non-synesthete can shed light onto the synesthetic perceptual process and in turn the normal perceptual process. Both the synesthetic and normal perceptual process have more to be expounded upon due to the ever-increasing abilities of technology and discoveries that are made through new technology (e.g., the fMRI giving way to knowledge of how stimuli are perceived visually through showing activation in the V4/V8 pathways, Nunn et al., 2002). Due to the widely-individualized perceptions of synesthesia, it is difficult to develop a specific guideline and set of psychological determining tests for synesthesia. For many years synesthesia was ignored by the scientific community and regarded as hallucinations of the people experiencing it. This discussion on synesthesia will provide the current knowledge on synesthesia and how it is diagnosed. The purpose is to document the growth in research and in science as time has passed.

A BRIEF HISTORY OF SYNESTHESIA

The first authentic accounts of synesthesia documented began in the early nineteenth century. That assumption is not to discount any accounts of possible synesthesia referenced before then, but with current evidence, the accounts before the nineteenth century do not hold to be factual (Jewanski, Day & Ward, 2009). The first known case of synesthesia is of Georg Tobias Ludwig Sachs (1812), which is documented in a medical dissertation Sachs wrote documenting his albinism, in which his synesthesia is referenced “abruptly and briefly” (Jewanski, Day & Ward, 2009). The next account of synesthesia does not occur for more than 70 years after Sachs’ dissertation, in which Sir Francis Galton describes synesthesia is his book Inquiries into Human Faculty and its Development (1883).

In the medical dissertation, Sachs (1812) describes “the brother” (himself) as having grapheme-color synesthesia where letters and numbers have colors. Along with the grapheme-color synesthesia, Sachs (1812) describes colored time units and sound-color synesthesia, all of which evoke a colored perceptual experience in “the brother’s” mind. In Sachs’ dissertation he does not associate his synesthesia with his albinism due to a referenced meeting of a man who experienced similar synesthetic qualities (Sachs, 1812; Jewanski, Day & Ward, 2009).

The next accounts of synesthesia come in the manuscript, Inquiries into Human Faculty and its Development (1883). Sir Francis Galton begins one of the chapters with a basic description of grapheme-color synesthesia, in which numbers and letters are viewed as having colors associated with them. Galton (1883) illustrates the synesthetes as not being content with giving a simple description of the color they are seeing, but would rather give a very specific detailed depiction of their synesthetic color. Due to the amount of detail given to Galton, he painstakingly detailed replications of the colors
and their associated letter or number in a set of figures within his book (Galton, 1883). The particularity of the synesthetes with their synesthetic colors is one that has been accounted for many times by researchers (e.g., see Robertson & Sagiv, 2005), which is of worthy notation to indicate that Galton was indeed working with individuals who experienced synesthesia.

After the account of synesthesia from Sir Francis Galton, research on synesthesia increased slightly until the early 1930s and was based, for the most part, on introspection accounts from individuals with synesthesia (Harrison & Barron-Cohen, 1995). Though, there is trouble with the reports of synesthesia from that time frame due to the reasoning that most documentation comes from introspection. Harrison and Barron-Cohen (1995) explain that introspection is an unreliable form of detailing human cognition, in that the subjects only report information that is different from what is regarded to be normal. To be completely accurate in an introspection description the subject would need to report every detail without a bias to shed themselves in a positive light.

Beginning in the 1930s behaviorism theories began to increase in popularity in psychology, due to its concentration on observable behaviors. The tangible display of behaviors, which can be observed and experimented on, dominated psychology for the entirety of the popularity of behaviorism. Therefore, research on synesthesia which relied on introspection and referenced a person’s mental state was subsequently disregarded from most research (Harrison & Barron-Cohen, 1995). It wasn’t until the 1970s that behaviorism began to lose popularity as some items could not be explained psychologically, such as the acquisition of language (Harrison & Barron-Cohen, 1995). Around that time, at the end of behaviorism, synesthesia began to increase in popularity and research subsequently followed to determine factors such as whether the condition was real and how the process worked.

The most important question researchers were aiming to answer in the early days of research on synesthesia was whether the condition was real and not a side effect of other disorders or substance abuse. To determine the authenticity of the condition, psychologists needed to be able to obtain physical and physiological evidence of the condition (Costa, 1996) rather than documentation of self-report. In a commentary on work by Cytowic, Costa (1996) emphasizes the need for new neuropsychological evidence to fully determine the validity of the condition. The need for new evidence is due to the reasoning that at the time of Cytowic’s review the new evidence showing cross modal communication was overlooked. The disregard of the new evidence was concerning for Costa considering it was the cornerstone of validating all accounts of synesthesia.

The criteria for any phenomenon to be accepted in the scientific community are very simple and follow three conditions (Robertson & Sagiv, 2005). The first must be that the phenomenon is real, which is what most of the early research on synesthesia sought out to display (Robertson & Sagiv, 2005). The next condition is that there must be some potential explanations for the development of the condition (Robertson & Sagiv, 2005), which is the reason for the genetic tests on synesthetes. The last condition is the phenomenon must be far-reaching in its associations and not be limited to one specialty (Robertson & Sagiv, 2005). Due to the acceptance of synesthesia as a condition in the scientific community researchers attempted create many different diagnostic tests to separate the true accounts from the fraudulent accounts of synesthesia.

Brain imaging techniques have been very useful in showing the validity of synesthesia and its authenticity by presenting the different brain area activations that are congruent with the experiences.
of the synesthetes. Through the different imaging techniques, it can be concluded that synesthesia is a real condition that affects a small portion of the population. The pairing of different sensory modalities which can be described in detail by the synesthete and shown through the brain imaging techniques give a possible explanation for the occurrence of synesthesia.

SYNESTHESIA TESTS

The first test to determine the validity of synesthesia was the test of genuineness, which was developed by Baron-Cohen, Wyke and Binnie (1987). The test of genuineness established validity of synesthesia by showing a consistency over time of the colors described by the subject upon hearing 50 meaningful word, the seven days of the week, 20 Christian names, and the 26 letters of the alphabet (Baron-Cohen, Wyke, & Binnie, 1987). After the initial test, the synesthete was tested again after a ten-week delay, in which the results showed consistency of the synesthetic colors chosen for each item (Baron-Cohen, Wyke, & Binnie, 1987). The test of genuineness created by Baron-Cohen et al. (1987) has been challenged in recent research on its validity by the modality and variability of the synesthetic experience due to the new research testing the consistency of the colors over a longer period such as a lifetime for the synesthetes (Brang et al., 2011).

The test of genuineness (Baron-Cohen et al., 1987) came with some limitations such as a reliance on the verbal description of color given by the synesthete. To decrease the limitations created by the original test of genuineness, researchers sought out to revise the test to produce less limitations and increase the accuracy for color-grapheme synesthesia (Asher, Aitken, Farooqi, Kurmani, & Baron-Cohen, 2006). The revised test of genuineness included a CD that contained 99 sounds, which were broken down into 51 words and 48 non-word sounds, and Pantone color swatches (Asher et al., 2006). The test was conducted in a room lit solely by artificial light and the subjects were instructed to choose the color swatch that closely related to the synesthetic color experience produced by the word heard, which followed the same categories as in the original test of genuineness (Asher et al., 2006). The synesthetes were retested with the same criteria for the revised test of genuineness after a minimum of one month to determine the consistency and validity of the synesthesia experienced by the subjects. The results from the revised test of genuineness were much like the results produced from the original test of genuineness. Due to the new criteria for testing, the results were more reliable since the colors were much more standardized.

Since the test of genuineness and the revised version do not offer quantifiable data for comparison, along with the fact there is no standardized scoring system or phrasing of questions, researchers have sought out to remedy this limitation of synesthesia research (Eagleman, Kagan, Nelson, Sagaram, & Sarma, 2007). Eagleman et al., (2007) developed the synesthesia battery which is comprised of a questionnaire (to determine type of synesthesia experienced) and software programs that offer immediate results for synesthetes and researchers. The synesthesia battery uses a standard scoring system to quantify results for the ease of data analysis and comparison (Eagleman et al., 2007). The other tests included in the battery are a grapheme-color consistency test, a speeded congruency test to detract cheating in the previous test, grapheme contrast to separate lower from higher synesthetes, and many other tests that are specific for the many other different types of synesthesia (Eagleman et al., 2007).
TYPES OF SYNESTHESIA

The process of synesthesia is one of automation (Ward & Mattingley, 2006) therefore it is easy to fall under the assumption that all synesthesia occurs through development. Although, that is not the case, some instances of synesthesia can be developed later in life either through substance abuse, brain injury, or a brain tumor. The three ways in which synesthesia can appear are developmental synesthesia (i.e., synesthetic perceptions that begin early in life), acquired synesthesia (i.e., synesthesia as the result of brain injury or brain tumor), and pharmacological synesthesia (i.e., synesthesia as the result of hallucinogenic substances) (Grossenbacher & Lovelace, 2001). The most researched of the three is the developmental type of synesthesia, which contains most of the different sensory modality pairings. The acquired and pharmacological synesthesia are less consistent and much less automatic; therefore, they are more difficult to research and have less subjects for research due to the methods in which the synesthesia occurs.

Sinke et al. (2012) describes pharmacological or drug induced synesthesia as a condition that is experienced temporarily under the effects of a hallucinogenic drug such as LSD. During the intoxication period, a dream-like state of consciousness occurs in which the hallucinations are manifested in the form of geometric patterns (Sinke et al., 2012). The synesthetic experience produced by the hallucinogenic drugs is a more abstract type of synesthesia and requires the state of mind drugs produce to be achieved; whereas developmental synesthesia is automatic and simple in the synesthetic perceptions. Due to the process in which the synesthetic experience is created, taking hallucinogenic drugs, research on the subject has not been performed often, or at all, in recent years. The reasoning behind the lack of research is made under the assumption that instructing participants to take hallucinogenic drugs for experimentation and observation would be considered unethical to the IRB (Institutional Review Board).

Another variety of synesthesia is the acquired type, where some type of brain injury or tumor has occurred within the sensory areas. The acquired type synesthete is not able to see a full range of colors as a developmental synesthete would, but rather they perceive colored flashes (Sinke et al., 2012). Consequently, acquired synesthesia is not as consistent as developmental synesthesia is, rather once a synesthetic perception pairing has occurred relative stability in the synesthesia is reached (Sinke et al., 2012). Although, current research has shown that the same stimulus may evoke a different synesthetic perception when viewed on different occasions due to the instability created by the brain injury (Sinke et al., 2012). Along with the instability of the sensory pairings the synesthesia event is not automated completely, as in developmental synesthesia, rather the perceptual events happen some of the time (Sinke et al., 2012).

As previously stated most occurrences of synesthesia appear through the developmental process where, for example, the synesthete will have always made the color-grapheme or sound-color associations and will not know a life without them (Robertson & Sagiv, 2005). The most frequently occurring type of synesthesia as shown by the synesthesia list (created by Sean Day; Day, 1992) is the color grapheme type, in which a color is synesthetically perceived when a letter or number (grapheme) is viewed by the subject (Brang et al., 2011; Day, 1992). Another interesting feature of synesthesia is that the synesthete’s attention can be switched between the printed and synesthetic color (Robertson & Sagiv, 2005). The ability for the
synesthete to switch between the two different perceptions is a particularly noteworthy feature of synesthesia since it is not a condition that can be fully or easily repressed as shown by Ward and Mattingley (2006).

Since the association of the color and grapheme are a determining factor for true synesthesia, it is an important finding that the subjects hold the same color and grapheme associations throughout a lifetime (Ward & Mattingley, 2006), which was shown by Baron-Cohen et al. (1987). The researchers revealed the color experienced by the synesthete typically does not change upon retesting of the association for that specific grapheme, through the test of genuineness (Baron-Cohen et al., 1987). The test of genuineness was created by Baron-Cohen et al. (1987) to be used to test the associations made by the synesthetes for consistency.

The way synesthesia can be perceived adds another factor into the idiosyncrasies of the condition. Currently, there are three different styles that are similar in their qualities. The first and most researched is associative vs. projector, which is the process where the stimulus will create a concurrent perception in either the “mind’s eye” (i.e., associative) or on the stimulus (i.e., projector) (Brang et al., 2011). The second way synesthesia is perceived is much like associative synesthesia, which is synesthetic conception, where the thought of a certain concept can induce the concurrent (synesthetic experience) (Grossenbacher & Lovelace, 2001). The converse of conception synesthesia is like projector synesthesia, and is called synesthetic perception which is when the concurrent or color is induced by the sensory stimuli (Grossenbacher & Lovelace, 2001).

The last way synesthesia can be perceived is intermodal vs. intramodal synesthesia. Intermodal (cross-modal) synesthesia is when the stimulus or inducer is in a different sensory modality than the synesthetic perception or concurrent (Robertson & Sagiv, 2005). An example of intermodal synesthesia is color-hearing in which a sound stimulus induces a visual color concurrent. Intramodal (cross-dimensional) synesthesia by comparison is different in that the inducer and concurrent are within the same modality, but differ in dimension (Robertson & Sagiv, 2005). An example of intramodal synesthesia would be the most frequent type of synesthesia seen, which is the color-grapheme type in which a visual grapheme stimulus induces a visual color concurrent.

GENETIC PREVALENCE OF SYNESTHESIA

To determine the genetic prevalence of synesthesia Baron-Cohen, Burt, Smith-Laittan, Harrison and Bolton (1996) conducted three separate studies. The first two studies were advertisements placed in two separate magazines, the former to reach the general public and the latter to reach students at the university (Baron-Cohen et al., 1996). The advertisements requested individuals who experienced synesthesia to contact the researchers; upon their responses two researchers from the group tested them for the genuineness of their synesthesia (Baron-Cohen et al., 1996).

The genetic prevalence finding from studies one and two found that for every six females that had synesthesia, one male also had synesthesia, giving a 6-female: 1-male ratio (Baron-Cohen et al., 1996). The higher female to male ratio indicated there was a genetic underlying in the development of synesthesia, which agreed with Rich, Bradshaw, and Mattingley’s 2005 findings. The same findings of a genetic prevalence over a longer period and from separate research groups give a strong indication that neither study discovered a fluke in the condition, but rather a genetic approach that needed further study.
The third study by Baron-Cohen et al. (1996) aimed to test the genetic prevalence of synesthesia by looking to familial aggregation, which is the grouping of certain traits, behaviors, or disorders. To determine the familial aggregation, Baron-Cohen et al. (1996) studied six families selected from the International Synesthesia Association’s cases who had established cases of synesthesia within the families. To establish the authenticity of synesthesia within the families, the researchers used the test of genuineness on the synesthetes and their first-degree relatives. The researchers found all families were a multiplex for synesthesia (Baron-Cohen et al, 1996).

From the results, Baron-Cohen et al. (1996) hypothesized three genetic explanations for synesthesia. These explanations were autosomal recessive (i.e., both parents must pass on at least one gene for synesthesia for the child to develop the condition), autosomal dominant with sex limitation (i.e., one parent passes the synesthesia gene to the child, mother to daughter, father to son), and sex-linked dominance with lethality (i.e., the synesthesia gene is X-linked and passed from mother to daughter, with a lethality from mother to son). The researchers determined at the time the most viable genetic explanation for synesthesia is the sex-linked dominance with lethality because it provides a reason for a female prevalence of synesthesia (i.e., 6:1 female to male ratio; Baron-Cohen et al., 1996). Although, more genetic pedigrees would be required to explain the expression of males with synesthesia due to the evidence of the synesthesia gene being linked with a lethality gene.

Even though synesthesia appears to be genetically linked, there is no explanation as to how there are so many different types of synesthesia (Brang & Ramachandran, 2011). For example, in families that express synesthesia, each member could have a different type of synesthesia (i.e., color-grapheme or sound-color), which gives the implication that the genetics give way to predisposition for the condition and not how it can be expressed (Brang & Ramachandran, 2011). Further research into the prevalence sampling studies also indicate there is less of a gender gap, which indicates there may have been flaws in the designs of the previous studies that gave a gender gap in the prevalence of synesthesia (Brang & Ramachandran, 2011).

**CURRENT RESEARCH AND FUTURE CONSIDERATIONS**

Researchers have made much progress in the standardization of testing for synesthesia, but it’s possible that a new test should be developed that can be easily used on the entire population (i.e., increase generalizability). The standardization of a synesthesia test would be beneficial for researchers to determine the true number of how much of the population synesthesia affects, since much of the current research indicate different numbers for the affected population.

Another discrepancy within the current research are the genetic implications of the transmission of synesthesia. The discrepancies within the genetics could be largely due to the high variability within the expression of synesthesia. Although, that does not seem plausible, in all the research, the researchers controlled for the variability in using the same type of synesthetes in the genetic comparisons. Therefore, it would be beneficial in the genetic research to determine why there are differences in the linkages on chromosomes. While the genetic linkage tests have shown there is some type of genetic linkage and familial linkage for synesthesia, there is not a clear explanation for the transmission. Upon further research, the genetic linkage of synesthesia should be further determined to give a
better indication as to how synesthesia is transferred from parent to child, along with how it is developed.

REFERENCES


INTRODUCTION

Chemotherapy is widely used in treating diseases such as cancer because of its ability to kill all cells, whether cancerous or healthy. Problems arise for the patient during treatment due to chemotherapy attacking all cells instead of the tumor cells exclusively [13]. Due to chemotherapy’s inability to target the cancerous cells it is said to be toxic to the body. As a consequence the chemotherapy has to be given in amounts that will not be overly toxic to the patient, while still reducing the size of the tumor. To reduce the amount of stress chemotherapy puts on the human body mathematical models are used to determine the levels of chemotherapy that are effective in killing the tumor [1,7]. Along with determining the correct levels of chemotherapy to use in treatment, it is necessary to find a proper schedule to give doses of the drug that would maximize efficacy and have a low overall toxicity [1].

There are two types of existing chemotherapy treatments commonly used, Maximum Tolerated Dose (MTD) and Metronomic Chemotherapy (MC) [2]. MTD chemotherapy is given in high doses with periods of rest between treatments in order to use the maximum amount of drug that is tolerated by the patient [2, 3]. Metronomic chemotherapy is the lowest amount of toxicity of chemotherapy administered over a longer period of time [2]. Both types of chemotherapy have specific benefits when treating certain types of cancer; for example, a higher dose may cease tumor growth when the
converse, a low continuous dose, may have no effect on the tumor [14]. When taking into consideration the different types of chemotherapy it is useful to develop a mathematical model to determine which type of chemotherapy has the greatest efficacy in treating the tumor.

To track the movement and toxic build-up of chemotherapy throughout the tumor and the body, experimenters have developed imaging agents that can bind to certain proteins to mimic the movement of chemotherapy [4, 5, 6]. The imaging agents are able to show where in the body, aside from the tumor, the chemotherapy has accumulated. The build-up of the imaging agent shows experimenters where the chemotherapy becomes lethally toxic [6]. The lethality of chemotherapy occurs when it has accumulated in an area that contains healthy cells, the cell death that occurs is considered harmful because the cells were not cancerous. It is important to develop a mathematical model that can compartmentalize the effects of chemotherapy in regard to toxicity in order to have less invasive procedures [6, 7].

Compartmentalized models are able to show the movement of the drug in and out of the tumor and various other organs such as the kidneys, which are involved in the filtering of the blood and excretion of waste [6]. Gompertz-type growth models take into account the slowing of tumor growth as the mass reaches a certain cell population level [1, 7]. It is important to take into consideration, when creating a mathematical model, that the tumor will decrease and increase in growth rates as the drug is being administered and the cells become resistant to the drug [7, 8]. The fluctuation of growth rates of cells in the tumor are due to the administration of the chemotherapy, especially the Maximum Tolerated Dose (MTD) treatment and the Gompertz style of growth [1,7,8]. The MTD chemotherapy treatment has a characteristic side-effect of fluctuating mass size due to the manner it is administered because of it is given in high doses and requires a rest period afterward to reduce toxicity [2,3].

It is our goal to develop a mathematical model for our PIC Math sponsor, the Moffitt Cancer Center, that has an optimal schedule that will maximize drug efficacy with the minimal amount of toxicity required. Such a model would be effective in suppressing tumor growth and be minimally harmful to the healthy cells. Due to the importance of toxicity outside of the tumor, a compartmental model is necessary to track the movement and build-up of the drug in the body. The mathematical models created will take into consideration both types of chemotherapy treatment, the Maximum Tolerated Dose (MTD) and the Metronomic Chemotherapy (MC) because each are important in showing the effects each type have on a tumor.

**MATHEMATICAL MODELS**

In designing the models, we begin with a simplistic approach. Drawing heavily from [7], the first model simply shows how tumor size changes over time. The only variables the model includes are a rate constant $k$ (Day$^{-1}$), cell population $T$ (mm$^3$), and the carrying capacity $T_\infty$ (mm$^3$). See appendix I for a table containing the variables described.

\[
\frac{dT}{dt} = kT\left(1 - \frac{T}{T_\infty}\right) \tag{1}
\]

Based on the previously listed simplistic mathematical model, we constructed our alternative models with regard to the simple models. In this mathematical model we start with the logistic growth model:

\[
\frac{dT(t)}{dt} = \lambda_e T(t)\left(1 - \frac{T(t)}{T_\infty}\right) - L(T(t), C(t)) \tag{2}
\]
The logistic growth model describes the relationship between the tumor growth and the effect of the anticancer drug. The first term

\[ \lambda_L T(t) \left( 1 - \frac{T(t)}{T_\infty} \right) \]

describes the increase in cells due to proliferation with carrying capacity \( T_\infty \).

\[ \lambda_L = \frac{1}{\tau} \left( \frac{T_\infty - T_0}{T_\infty / 2 - T_0} \right) \]

\( \lambda_L \), the tumor growth rate is a constant and is calculated from the tumor doubling time \( \tau \). Initially, the solution explodes exponentially at a rate \( \lambda_L \) (tumor growth rate), which eventually converges to the equilibrium value \( T(t) = T_\infty \) for the population over time. The second term

\[ L(T(t), C(t)) = k(C(t) - C_{thr})H(C(t) - C_{thr})T(t) \]

describes the decrease in cells due to drug. We begin the equation with the drug’s specific kill rate, \( k_{eff} \), which is a major determining factor in the effects of the drug. We then multiply by the amount the concentration is above the threshold, \( C(t) - C_{thr} \), to prevent errors from occurring when the concentration is below the drug’s threshold, we multiply by the output of our Heaviside function, \( H \). Thus far, we are essentially representing how much of a given volume would be killed by the drug, finally we multiply by the tumor’s volume at time \( t \), \( T(t) \), to reach a complete model for cells lost due to drug treatment. \( H \) is a Heaviside function where:

\[ H = \begin{cases} 
0 & \text{if } C(t) - C_{thr} < 0 \\
1 & \text{if } C(t) - C_{thr} \geq 0 
\end{cases} \]

As mentioned in [1, 7], such simple models are unable to accurately portray complex growth dynamics. Merely utilizing a rate constant to control growth rate is a rather naive method of constructing a model, when in experiments growth of a cancer does not resemble a linear function. Instead, a Gompertz style equation, one which replicates the results of tumor growth slowing due to decreased nutrients and increased cell density, is used to more accurately reproduce experimental data. The second equation thus shows how tumor volume at a given time, \( T(t) \) (mm³), changes with time \( t \) (days).

\[ \frac{dT(t)}{dt} = \frac{1}{\tau_g \ln[\theta_g/T_0]} T(t) \ln \left[ \frac{\theta_g}{T(t)} \right] - L(T(t), C(t)) \quad (3) \]

In this equation, we have two contributing parts. The first we will detail is the first half:

\[ \frac{1}{\tau_g \ln[\theta_g/2T_0]} T(t) \ln \left[ \frac{\theta_g}{T(t)} \right] \]

Growth is modeled using variables of plateau size \( \theta_g \) (mm³), tumor doubling size \( \tau_g \) (days), initial tumor volume (mm³), and “\( \theta_x \)”, which was incorrectly typed in [7], as it was meant to be \( \theta_g \) (mm³). These are input into a standard Gompertz growth model, representing the natural growth of the tumor unimpaired by the introduction of the drug. As such, inputting \( L=0 \) (Cell number) would model an untreated tumor giving a starting point for our mathematical models [7].

The later half, \(-L(T(t),C(t))\), represents the efficacy of the treatment, measured as tumor cell loss due to therapy. The function \( L(a,b) \) is a measurement of the cells lost, with inputs \( a=T(t) \) being the tumor volume at time \( t \) and \( b=C(t) \) (ng/mm³) being drug concentration at the tumor site.

The assumptions for the drug concentration mathematical models are, drug is administered by
infusion, there is an instantaneous mixing of the drug with plasma, there is an immediate delivery of the drug to the tumor site, and the drug fluid dynamics mimic the florescence used in the mouse model graphic simulation data given by the client.

**DRUG CONCENTRATION PROFILE**

There are three compartments being considered for the drug concentration profile. The three compartments are concentration of drug in the blood, the tumor, and the other tissues. The following tables give the parameters and the description used in the drug concentration profile. See appendix I for a comprehensive legend of variables and parameters used.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>$BL(t)$</td>
<td>ng/mm$^3$</td>
<td>[Drug in Blood]</td>
</tr>
<tr>
<td>$TL(t)$</td>
<td>ng/mm$^3$</td>
<td>[Drug in Tumor]</td>
</tr>
<tr>
<td>$NL(t)$</td>
<td>ng/mm$^3$</td>
<td>[Drug in Other Tissues]</td>
</tr>
<tr>
<td>$T(t)$</td>
<td>mm$^3$</td>
<td>Tumor Volume</td>
</tr>
</tbody>
</table>

The values for the parameters used are obtained from [7]:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value ($d^{-1}$)</th>
<th>Parameter (Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_{10}$</td>
<td>151.2 $d^{-1}$</td>
<td>Blood Outbound</td>
</tr>
<tr>
<td>$k_{12}$</td>
<td>5.62 $d^{-1}$</td>
<td>Tumor Inbound</td>
</tr>
<tr>
<td>$k_{21}$</td>
<td>2.31 $d^{-1}$</td>
<td>Tumor Outbound</td>
</tr>
<tr>
<td>$k_{13}$</td>
<td>5.62 $d^{-1}$</td>
<td>Other Tissue Inbound</td>
</tr>
<tr>
<td>$k_{31}$</td>
<td>2.31 $d^{-1}$</td>
<td>Other Tissue Outbound</td>
</tr>
</tbody>
</table>

**TOXICITY MODEL**

The following table gives values to the parameters used in the toxicity model. These values were obtained from [7]:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$NL_{\text{max}}(t)$</td>
<td>50 d</td>
</tr>
<tr>
<td>$NL_{\text{cum}}(t)$</td>
<td>2.1x10$^3$d days</td>
</tr>
<tr>
<td>$t$</td>
<td>84 days</td>
</tr>
</tbody>
</table>

The model

$$0 \leq NL(t) \leq NL_{\text{max}}$$  \hspace{1cm} (7)

limits the drug concentration in nonspecific tumor site between a lower and an upper bound at each drug administration. The model

$$\int_0^T NL(t) dt \leq NL_{\text{cum}}$$  \hspace{1cm} (8)
places an upper bound on the total cumulative toxicity at the end of the treatment period.

In the toxicity model our group takes into account drug decay rate. We assume drug decay rate to be equivalent to recovery from toxicity in order to have a more accurate model for toxicity, since toxicity recovery cannot be implemented directly. The equation below depicts how we take into account the drug decay rate.

\[ (k_{12})(BL)\left( \frac{V_B}{VN} \right) - (d)(DK) \]  

This is a measure of the amount of drug entering the body minus the current concentration of the drug multiplied by its decay rate (days\(^{-1}\)), \(d)(DK)\).

RESULTS

Our immediate results with the mathematical models were very basic in terms of what was modeled and the parameters used. Initially we developed two basic graphs in order to test the Gompertz model code without the drug included. Our group did this to see the uninhibited tumor growth in the model we used. The parameters that differed between the two models were initial tumor volume and time.

Figure 1 depicts the tumor initial volume starting at an arbitrarily selected 80 mm\(^3\) and measures the growth rate without drug for a span of 180 hours. This graph is able to portray a correct Gompertz growth style curve, which indicated a successful simple mathematical model.

Both graphs are a comparison of tumor volume (y-axis) and time (x-axis) to show the uninhibited tumor growth over time. By using the different tumor initial volume sizes our group was able to see the importance of the parameter in our development of accurate mathematical models for drug efficacy and toxicity.

The next graph (figure 3), we developed upon client request. Our client requested we test our mathematical model by matching the data provided in graph E (figure 9). The data provided by the client was obtained through bicarbonate therapy experimentation with mice. The data in the graph were the points we compared all data produced by our

Figure 2 shows the second graph developed; which is measured for a longer period of time, 350 hours, and has a tumor initial volume of one cell. The one cell start size was chosen to replicate a cancerous cell that begins over replication from a simple mutation of a healthy cell.
models to, in order to have a more accurate depiction of the drug efficacy. The bicarbonate therapy data in the graph was given to our group by the client as a comparison for the florescent dye we were to model in our mathematical models created.

Figure 4 is an early graph of our group’s attempts at modeling uninhibited tumor volume and tumor volume when treated with the drug. In figure 4 uninhibited tumor size is measured by the red line and the treated tumor is measured by the blue line. In this early iteration of drug scheduling, the tumor volume is affected by each dose of the drug which is denoted by each peak in the blue line on the graph. The graph’s only successes are in showing tumor volume and the effects of the drug.

Figure 5 shows an early iteration of our attempts at trying different options with the drug scheduling and toxicity levels, the first option being Maximum Tolerated Dose (MTD) treatment. In this graph dosing is based on set time intervals, which can be changed as seen fit by experimenters. The graph demonstrates the tumor volume beginning to be affected by the drug scheduling, showing that our group was on the right track as far as scheduling and drug concentration were concerned for a MTD type of treatment.

Figure 6 was our next option for drug scheduling and toxicity measurement, Metronomic Chemotherapy (MC) treatment, which caps dosing when toxicity threshold is reached. Figure 6 had less peaks and had much smoother lines because of the constant drug administration due to the specifications of metronomic chemotherapy. Therefore, the graph accurately depicts the administration of drug over a constant time interval, only stopping drug treatment when the toxicity threshold is reached.

In the graph the light blue lines show what happens once the toxicity threshold has been reached. That is, the drug administration will stop until toxicity has decreased and then will begin again once
toxicity is below threshold, creating the appearance of a line with many points close together on it. Due to this feature of toxicity and drug concentration levels explained by metronomic chemotherapy treatment our group tried to stray away from it in our final models.

For both of the early attempts of our modeling all six compartments are shown in the graphs (figures 5 and 6) by a different colored line. The green line in each of the graphs shows the uninhibited tumor growth, while the purple line is the tumor treated with drug. The orange line on the graphs is the drug concentration in the non-specific tissues. The red and light blue lines show drug concentration in the blood and toxicity respectively. The dark blue line depicted the drug efficacy for the treatment being used.

In figure 7, modeling a MTD drug schedule, we implemented a two day on, one day off schedule. Simply put we administered drug for two days and left treatment alone for one day. The graph shows uninhibited tumor growth in green, and treated tumor growth in blue. Again, the graph compares tumor volume, with a maximum of 1800 (mm$^3$), (y-axis) and time for twenty-five days, (x-axis).

The final graph (figure 8) modeling a MC treatment schedule shows that the tumor responds to treatment until the toxicity threshold has been reached. Once the toxicity threshold has been reached the tumor begins to stop responding to treatment due to there not being enough drug administered to affect it. The green line, again, displays an untreated tumor with the blue line representing a treated tumor. The red line shows the toxicity levels where the y-axis on right side of the graph shows the toxicity levels in ng/mm$^3$.

See appendix I - Tables and Graphs, for further simulations of the mathematical models for MTD and MC chemotherapy, along with a graphic of a mouse model at three days of tumor treatment.
DISCUSSION AND CONCLUSIONS

The two Gompertz growth model graphs have shown our group an important aspect of the research we are doing. That is the starting point and data we use are critical in developing a working and accurate model to use in cancer research.

Another important aspect we learned as we created the models was that toxicity levels compared to drug concentration have a great impact on how much the tumor will react to the treatment being given. The Metronomic (MC) treatment schedule, shown in figure eight, is a good example of that because once the toxicity threshold has been reached the tumor does not react as much to the drug administration. The model shows that the tumor begins to start growing again, showing that it is not an affective treatment for the cancer. While, the Maximum Tolerate Dose (MTD) schedule (figure 7) appears to have more of an affect on the tumor by decreasing the amount that it can grow by. The tumor is immediately affected by the drug and does decrease in size and growth, but as soon as the drug stops being administered the tumor begins to grow again, therefore, causing the treatment to not be affective enough to completely eradicate the tumor.

In attempting to develop a toxicity measure our group has come across an issue with the method in which drug toxicity is measured, which is through a standard weight loss model. The main problem with the weight loss model is that cancer patients naturally loose weight due to the disease, so it is hard to determine what weight is lost due to the drug alone. When the tumor is responding properly to treatment, it should be shrinking as well, which in turn can cause an amount of weight loss. Thus, we cannot correctly assume all weight lost is due to the tumor loosing mass. Due to the unknowns that come with the weight loss models, it is incorrect to assume that all weight lost during treatment is due to toxicity of the drug. Therefore, in order to implement a toxicity model that had less assumptions we used a model that accounts for the drug decay rate and the amount of drug that is in the non-specific tissue. The model allows us to get a better picture of the drug concentration of the entire body and not just the tumor, therefore giving us a more accurate toxicity measure.

LIMITATIONS

Throughout our equations, we assume a compartmentalized model. As mentioned previously, this is both a more simplistic and more accurate representation of tumor-drug dynamics. In this manner, we are able to study the effects of the chemotherapeutic toxicity on each compartment. A limitation of our modeling is the requirement of representing flow of near infrared florescent dyes, as their flows are the only data we were provided. We are aware that the dynamics of these dyes may not mimic the flow of the drug, and have taken measures to report the differences between the dye and drug accordingly.

Another limitation of our model is the inability to properly compare our data produced from our models to that of the florescent imaging agent due to the lack of ability to interconvert the data. Due to that fact, we reached out to our client to determine the best possible solution to our problem. At this point we have decided to compare them based off of equivalence.

Our greatest limitation in our models has stemmed primarily from the lack of usable data. In reaching out to our client, we were discouraged from looking into particular parameters (namely results from an unspecified paper on bicarbonate therapy).
The reason for our interest in the parameters from the bicarbonate therapy were due to the fact that the data given to us from the client stemmed from that research. Therefore, all data has been suggested to be extrapolated from the following graph; Graph E:

**FUTURE WORK**

In future work our group aims to create an alternative model that can better incorporate additional parameters such as: vasculature of the tumor and surrounding organs, tumor density, drug uptake patterns and resistance. Upon completion of our alternative model we intend to produce a mouse model graphic simulation that can take into consideration the different veins and arteries that will come into contact with the tumor. The proximal vasculature is important to model due to the complexities that arise because the tumor has the ability to restrict blood flow, which will effect how much drug is able to get into the tumor.

**ACKNOWLEDGEMENTS**

"PIC Math is a program of the Mathematical Association of America (MAA) and the Society for Industrial and Applied Mathematics (SIAM). Support is provided by the National Science Foundation (NSF grant DMS-1345499)."

**REFERENCES**


The American Cancer Society medical and editorial content team. “How is Chemotherapy used to treat Cancer?” https://www.cancer.org/treatment/treatments-and-side-effects/treatment-types/chemotherapy/how-is-chemotherapy-used-to-treat-cancer.html (Updated February 16, 2016)
## APPENDIX I - TABLES, GRAPHS, AND ADDITIONAL FIGURES

### Variables and Parameters for Mathematical Models 1, 2, 3

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<th>Value</th>
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<td>Final Time</td>
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0.0.1 Scheduling and drug concentration 1:

\[ U = \begin{cases} 
0.02 & \text{if } t < 175 \\
0.01 & \text{if } 175 \leq t < 275 \\
0.001 & \text{if } 275 \leq t < 300 
\end{cases} \]

Vary drug exit rate, \( a_{10} \) from the system, fix drug kill efficiency \( k = 240 \):

Vary drug kill efficiency, \( k \) and fix drug exit rate \( a_{10} = 80.5 \text{d}^{-1} \):

0.0.2 Scheduling and drug concentration 2:

\[ U = \begin{cases} 
0.0 & \text{if } t < 25 \\
0.001 & \text{if } 25 \leq t < 155 \\
0.02 & \text{if } 155 \leq t < 175 \\
0.01 & \text{if } 175 \leq t < 275 \\
0.0 & \text{if } 275 \leq t < 300 
\end{cases} \]
Vary drug exit rate, $a_{10}$ from the system, fix drug kill efficiency $k = 240$:

Vary drug kill efficiency, $k$ and fix drug exit rate $a_{10} = 80.5d^{-1}$:

0.0.3 Scheduling and drug concentration 3:

\[ U = \begin{cases} 
0.0 & \text{if } t < 25 \\
0.009 & \text{if } 25 \leq t < 100 \\
0.01 & \text{if } 100 \leq t < 155 \\
0.02 & \text{if } 155 \leq t < 275 \\
0.0 & \text{if } 275 \leq t < 300 
\end{cases} \]
Vary drug exit rate, $a_{10}$ from the system, fix drug kill efficiency $k = 240$:

Vary drug kill efficiency, $k$ and fix drug exit rate $a_{10} = 80.5d^{-1}$:

0.0.4 Scheduling and drug concentration 4:

$$U = \begin{cases} 
0.0 & \text{if } t < 25 \\
0.03 & \text{if } 25 \leq t < 100 \\
0.0 & \text{if } 100 \leq t < 115 \\
0.03 & \text{if } 115 \leq t < 175 \\
0.0 & \text{if } 175 \leq t < 200 \\
0.2 & \text{if } 200 \leq t < 300 
\end{cases}$$
Vary drug exit rate, $a_{10}$ from the system, fix drug kill efficiency $k = 240$:

![Figure 10: MTD Mouse Model. (Green dot - untreated tumor; Blue dot - treated tumor.)](mouse.png)

Vary drug kill efficiency, $k$ and fix drug exit rate $a_{10} = 80.5d^{-1}$:

![Figure 11: MC Mouse Model. (Green dot - untreated tumor; Blue dot - treated tumor.)](mouse.png)
The Debilitating Effects of Discrimination: A Case Study on Disability in the Workplace

Jeffrey Stuart & Wendy Hinshaw

For years, people living with disabilities have faced daily stigmas. Their public and professional lives can often be unsupported and unsafe, which can lead to discrimination, particularly in the workplace. This research represents six months of on-site observation at Boca Raton’s Habilitation Center for the Handicapped, one of South Florida’s largest employers of people with disabilities, and discusses how they are working internally to empower their employees and clients by moving beyond the continued stigmas. While focusing on what the discriminations towards individuals with special needs in the workplace are, why they exist, and what is being done to facilitate change, this study will also observe the difficulty of inclusion while emphasizing its importance.

Whether it is cognitive or physical, those living with disabilities face daily prejudice. While great progress has been achieved for the rights of people with disabilities, there are still multiple issues that must be addressed. One such issue is that of employment and the stigmatization that exists in the workplace. An increasing number of businesses and organizations are working not only to assist with the employment rates of people with special needs, but also to provide them with the proper conditions conducive to a healthy working environment. South Florida’s Habilitation Center represents a powerful case study for workplace disability advocacy in that they create a very necessary, yet isolated safe space where those with varying disabilities can work. While working internally to assist in the empowerment and local employment rates of people with disabilities, their work can help to understand disability advocacy in a larger context. This research will observe what the Habilitation Center is doing to facilitate change, how they work to empower their demographic in a controlled atmosphere within a climate of continued prejudice and discrimination, and why the stigmas associated with the under-employment, under-utilization, and undervaluing of people with disabilities exist.

In terms of employment, disability advocacy gained momentum when Congress passed the Americans with Disability Act (ADA) in 1990. Enforced by the Equal Employment Opportunity Commission (EEOC), this act addressed their rights and needs and prohibited discrimination both in the workplace and in public. Decades before the ADA however, people with disabilities, their families, and supporters were challenging the societal barriers that excluded them from their communities.
Many of them fought for individual rights and for the establishment of the independent living movement, which fought against the preconceived notion that people with disabilities should be institutionalized (Mayerson, 1). Without these efforts, Equal Employment Opportunity would not include the support of people with special needs.

South Florida’s Habilitation Center, more commonly known as the HabCenter, is a non-profit organization who acted as a pioneer in the fight for workplace advocacy of people with both cognitive and physical limitations. In 1978, their services became available to adults with all forms of developmental and intellectual disabilities and since then, they have become one of Florida’s leading disability advocates. They offer vocational and job training programs, supported employment, as well as employment opportunities on location. More importantly, they do this in an isolated, safe environment, free from the stereotypes and exclusions some individuals may face in public. To some however, this may exacerbate the idea of keeping people with disabilities “invisible” to the public eye. While this happens to be a popular strategy utilized by many businesses and organizations, it can present challenges.

Mainstreaming refers to the public process of supporting programs to find ways of responding to the multiple needs of people with disabilities and involves the inclusion and integration of those with special needs among those without. In most cases, the idea of mainstreaming relates to education and employment, where it presents both advantages and disadvantages. Regarding the social and professional aspects, mainstreaming allows individuals to interact and engage side-by-side with their non-disabled peers. This can lead to the development of skills that may not have otherwise been acquired. It also allows for the promotion of tolerance: those without disabilities would not have the opportunities to interact with and learn more about people with disabilities without immersion programs and inclusion. Yet, the same disadvantages exist in the workplace. There have been instances where people with disabilities have dealt with embarrassment and self-esteem issues stemming from mockery and a lack of understanding from their coworkers. The HabCenter understands that these disadvantages can lead to discrimination. This seems to be the reason for their ideology when it comes to the privacy of their clients and employees. What the organization does is necessary and for decades they have continued to provide advocacy for disabilities, but is it possible that their reclusive nature and a lack of a push for mainstreaming their organization is detrimental to the expansion of their cause?

A majority of what the HabCenter does for disability advocacy is achieved internally. While many other companies run social media campaigns and attempt to network and branch outwards, the HabCenter, for the most part, attempts to change perceptions from the inside. By providing individuals with the necessary skills to become independent and productive members of society, they are taking the necessary steps for mainstreaming in the workplace. By working on motor skill function, improving cognitive abilities, and focusing on social interaction, the HabCenter prepares their clients by furthering their assets to the best of their abilities. And while their work towards disability advocacy in the workplace is immeasurable, in terms of public immersion and awareness, the HabCenter remains relatively quiet. While they do hold annual benefits and charities, they are not often present at advocacy events or disability expositions promoting their cause. It is difficult for them to spread their message to a broader audience and advocate on a larger scale due to the tensions between the idea of the visible and invisible. The visible, being outward advocacy of those with disabilities, and the invisible being a protective separating from society. Should those with
disabilities be exposed to elements that may cause displeasure, or should those elements be made more accommodating towards those with disabilities? The lack of general social acceptance that the majority exhibits towards people with disabilities makes this a difficult task, and forces organizations such as the HabCenter to operate in the shadows.

In the early years of the HabCenter ranging from the mid to late 1980’s, the percentage of people in the United States diagnosed with a disability was approximately 3.4%. According to a 2015 study conducted by the Center for Disease Control, the rate has increased to an estimated 22%. This includes cognitive and neurological disorders, cardiovascular conditions, respiratory problems, musculoskeletal issues, sensory processing disorders, speech delay and non-verbal diagnoses, and an increase of addition medical complexities. Out of the 22% of people with disabilities, only 13% have mobility issues and 10.5% have cognitive impairments, while another 6.5% have trouble living independently, and 3.6% have self-care impairments (Center for Disease Control). This indicates that more than half of people with disabilities are cognitively and physically able. In Florida, 12.8% of the state’s population suffer from some type of disability, where 31.3% of that population is employed and only 19.1% of those employed are working full-time (Flexer). Compared to the national level, 17.5% of people with disabilities are employed and almost one-third of those employees are part-time. Many of these individuals tend to work more in production, transportation, and material moving occupations and less in management, professional, and related occupations (U.S. Bureau of Labor). These employment problems suggest that disabled individuals do not have adequate opportunities to experience satisfying careers or achieve their potentials in a professional setting.

Workers with disabilities tend to report lower levels of satisfaction with their jobs as compared to non-disabled worker. This can be attributed to working conditions, discrimination, poor interpersonal relationships, harassment, and low pay. On average, people with disabilities make $9,000 less than those without a disability (Uppal, 337). Considering that the cost of living for someone with disabilities is considerably higher than those without, this can be devastating. And while people with disabilities might receive stipends from the government, they are typically not enough to cover basic living expenses. A report in 2015 by the Bureau of Labor and Statistics claimed the average monthly disability benefit is $1,165 for unemployed adults with disabilities (U.S. Bureau of Labor). This is barely above the poverty line, and again, because the cost of living with a disability is so high, these numbers can be detrimental to the quality of life.

The HabCenter attempts to accommodate all the needs of individuals living with any debilitating conditions. While many companies are advocates for the employment of people with disabilities such as Publix, Walmart, Target, and numerous fast-food chains, in most cases their employees do not have access to disability training. Much of the success of the HabCenter relies on the training of their clients and employees to prepare them for their integration into the “real world”. Several companies fail to prepare their employees for the integration of workers with disabilities and it results not only in potential lawsuits, but in a lowered quality of life. Whereas places like the Habilitation Center specialize in the hiring, training, and habilitating of people with disabilities. This training assists in an elevated quality of life, a higher income, and stronger interpersonal skills that are often demanded of people in a professional environment.

The occupational services provided by the HabCenter allow for the clients and employees to feel a great sense of accomplishment, pride, and connectivity to not only themselves but to their
community in a professional sense. In a social sense, they are somewhat secluded from the community due to the stigmas surrounding both the business and residential world. The fact that their employees possess cognitive and physical disabilities is readily available information, however this is not broadcasted or advertised on a large scale. Again, falling victim to this idea of the visible and invisible. With internal knowledge of the organization, one can observe the scale of its achievements and notice that great change is implemented from within, however to the outside world little is known or perceived of the HabCenter, their clients, or their employees. Considering the quiet nature of the organization, their impact on the community is larger than expected, however with implementations of programs that increase disability awareness, and a stronger external campaign, their organization could make an even larger, more imperative impact.

The stigmatization that occurs towards individuals with disabilities in the workplace lies within the employers’ stereotypes, discriminations, and biases. Unfortunately, there are some companies that view people with disabilities as disadvantages, with many of the biggest complaints being a lack of speed and productivity. In a time of instant gratification and satisfaction, those who cannot meet specific expectations tend to get left behind. Many employers refuse to commit the extra, yet necessary time to accommodate those with special needs. Additionally, employers also express concerns with updates in accommodations to infrastructure, such as building, access ramps, and the learning of new technologies. Some employers worry about the health risks associated with certain conditions and the missed workdays as a result. These concerns are often misinformed opinions due to a lack of information about the disabled demographic. Studies show that workers with disabilities miss the same, if not fewer days than their non-disabled coworkers, and in many cases, due to a higher focus on safety precautions, they often have higher safety records (Stone, 353). Additionally, many individuals with disabilities excel with regards to technology, typically from being acquainted at an early age.

Another issue is the lack of social acceptance displayed by non-disabled people. This is often a reason why people with disabilities fail to stay employed for extended periods of time (Vornholt, 471). Whether it is direct or indirect insults, harassment, abuse, staring, isolation, or a general lack of understanding, people tend to make the daily lives of those with disabilities difficult, particularly in confined working environments.

The attitudes of people without disabilities towards their disabled co-workers can be attributed to several reasons. Primarily, there are the notions of performance and independence. One study showed that the better the performance of an employee, the more they were accepted by coworkers and management, regardless of his or her disability. The same was true for individuals with physical limitations or mental impairments that could work independently. The more independently someone could work, the greater the level of acceptance (Thibodeaux). Despite this, the lack of sensitivity training and disability awareness in the workplace remains problematic for most of those living with a disability. Several companies also maintain the perception that hiring someone with a disability will cost more money than someone without. Studies show that the costs of adjusting to accommodate employees who are disabled are quite low. Most structural changes such as wheelchair ramps and other accommodations are generally required by law and are of no extra cost to employers. The most common argument for the cost of hiring someone with a disability is the time it costs to train. Again, studies have shown that some non-disabled workers may take equal, or even longer amounts of time to train. The HabCenter allows
for the pre-training of individuals which eliminates this concern, and with a greater number of companies who specialize in this service, other organizations would find an easier time with the acclamation of already trained employees.

The importance of employment is not only for financial gain, but it fulfills numerous basic human needs. Some of those needs being activity, social contact, status, time, structure and a collective purpose (Vornholt, 470). This is what the HabCenter achieves through their programs, not only by producing a sense of productivity, but also by preparing people to integrate themselves into the community in ways that may otherwise not be available to them. Opportunities such as the Supported Employment Program allow them to find jobs in their community, and their on-site manufacturing company, HabCo Manufacturing, allows job training in turnkey style products such as circuit board and cable assembly, product testing, cell phone repair, wire harnessing, and various other job options. In 2015, HabCo Manufacturing won South Florida Manufacturer of the Year, offering numerous services to companies nationwide. Despite this recognition, the public perception of the efficiency and productivity of employees with disabilities is underwhelming.

Dedicating time to ensure the comfort of those with disabilities is crucial in making sure discrimination does not occur in the workplace. Quality control is a key factor in HabCo’s success. While every company maintains quality control to accommodate the needs of those with disabilities, at HabCo, sometimes quality control checks must be performed more than once. That is, when a task is completed, sometimes the work must be checked multiple times to maintain quality of the products, whereas other companies may only have to do these tasks once or twice. While there are extra steps involved, these are small and reasonable accommodations that several companies could make without a large sacrifice.

Large corporations such as Walmart, Ikea, Goodwill, and McDonalds launch annual campaigns to spread disability awareness. Walgreens promotes disability inclusion on their website in addition to annual campaigns. Target not only employs those with special needs, but they have begun to use people with disabilities in their advertisements. Unlike the HabCenter however, these companies promote disability awareness externally through campaigns, but often when it comes to the internal practices, they lack the experience and knowledge to conduct proper training sessions. The HabCenter’s business model could be mutually beneficial to both the employee and employer if it is to be followed. This is not to discredit the outwards promotion of disability awareness. Contrarily, the HabCenter could benefit a great deal from external promotion. More importantly, the disabled community could benefit from organizational expansion with companies like HabCo and programs offered by the HabCenter itself. Without the external promotion of their missions, the HabCenter will struggle to expand. Thus, only a limited number of services will be available to those in need. It will take both the internal and external accomplishments of these organizations to change the perceptions towards disabilities.

Many people with special needs struggle with the difficulties of daily living skills, sometimes with the most basic tasks. Whether it is health and well-being, financial needs, or the necessity to learn and develop skills, there are many avenues in which these can be achieved. Enabling access to mainstreaming systems will be necessary to involve people with disabilities and to increase public awareness and understanding. This can be gained through improved and more widely supported research on disabilities. On a national scale, adopting a disability strategy and plan of action would be beneficial to both individual and business (World Health Organization, 265).
The concept of “disability” is fraught with stigma, bias, and discrimination, which results in both social and work life being unsafe and unsupported. Ultimately it is up to us as human beings to learn and spread awareness about disabilities. People tend to fear what they do not understand, and they are often apprehensive towards the unfamiliar. As with any other prejudice, it is crucial that we alter the existing beliefs about the individual and introduce more accurate and factual beliefs. The Habilitation Center provides an impressive internal business model that if followed on a greater scale, can provide those with disabilities the support they need to feel less discriminated against in the workplace. Despite their private nature, the HabCenter works to circumnavigate the turbulent world by preparing those with disabilities for an inclusive life in a professional, relaxed, and safe atmosphere. With an increase in organizations and businesses like the Habilitation Center, access to mainstreaming, improved human resources, involvement, and increased public awareness, the stigmas that exist towards those with disabilities can be challenged. As history has shown, knowledge leads to understanding and that is a vital part to the betterment of the lives of those with special needs.

WORKS CITED


Author Biographies

**Jeanelle C. Angus** is a recent graduate of Florida Atlantic University with a concentration in Women's Studies/Sociology. Recently, she presented her research at the Florida Undergraduate Research Conference (FURC), the Literary Festival 2017 Student Research, and was fortunate to receive a grant from the Office of Undergraduate Research and Inquiry and the FAU Wave program. She enjoys volunteering, motivating young men and women, and implementing solutions to end societal issues. She currently is studying and preparing for the LSAT. She plans to apply to Columbia, Cornell, or Boston University Law School with the hopes of eventually expanding her research, obtaining a J.D., and becoming a civil rights attorney.

**Catherine Berrouet** is a young mathematician in the making. The rigorous process has taught her for the better. Growing up in a big city with no siblings, Catherine didn’t have too many friends. Naturally, she’s had a passion for math and the arts. However, lack of support and guidance from family and friends, made it easy to graduate from the University of Florida in a major other than math or dance. Catherine excelled in her studies and was hired in the utopic city of Key West immediately after graduating. She found herself always tutoring math to others on the job. Finally, after five years, the idea to return to school to pursue her passion, Mathematics, thrilled her. Today, Catherine is an undergraduate mathematics major, within Florida Atlantic University’s College of Science. Best known for her diligence and happy-go-lucky attitude, she aspires to apply for graduate school in 2018.

**Nic Haylett** is a senior Literature student at the Harriet L. Wilkes Honors College. Haylett joined the Harriet L. Wilkes community of scholars after transferring from their previous institution, Appalachian State University in Boone, North Carolina, where they studied English and Communications for one year. Haylett’s research interests include Renaissance and Early Modern Literature and Culture, 20th Century American Poetry, and Contemporary Television and Film Studies. Haylett aspires to teach high school English; they are an activist for education reform, and hope to help usher in an education culture where students of all genders, abilities, classes, races, and sexualities are given equal opportunities.

**Celina Kreidy** is a senior at the Wilkes Honors College at Florida Atlantic University with a concentration in Psychology. Social Psychology peaks her interest as it explores an array of social dynamics and relationships. The inspiration behind researching women and leadership was from her Psychology, Women and Writing class and Sheryl Sandberg’s book *Lean In: Women, Work and the Will to Lead*. She is also a co-founder of the Honors College Psychology Club that hosts events to educate and inform students of various psychological topics such as mindfulness activities during the club’s semi-annual Stress Less event. Her interest is also in writing plays and screenplays. She has recently written a play based off the research of leadership styles of women and how they are perceived by those they work with.

**Rafael Leite** graduated from Florida Atlantic University in May 2017 with a Bachelor’s of Arts in Psychology along with a minor in Spanish and Sociology. He has been a member of the Alliance Lab since January 2016 and had the opportunity to present his research and complete an Honors Thesis. Rafael hopes to pursue the field of psychology and continue research on multicultural counseling and psychology.
Elizabeth Manzano is pursuing a BS in mathematics. She is from West Palm Beach, Fl. After graduation, she intends to go into the aerospace field and work as a statistician. She spent two years at the University of Florida and is completing her degree at Florida Atlantic University. Her interests outside of mathematics include music history, vocal performance and playing the violin and viola.

Eric Terpstra is currently working towards his BS in Mathematics at Florida Atlantic University. He is from Delray Beach, Florida. He plans to study cryptography at FAU and continue conducting research at the school. He also has a passion for languages, and hopes to study them more in the future. Once he finishes his formal education, he hopes to work in the field of cyber-security.

Mukunda Pudasiani was born in Lalitpur, Nepal in 1983. He received his BS in Physics (2004) and MS in Physics (2006) from Tribhuvan University, Kathmandu, Nepal. He was an instructor for undergraduate Physics at Orient College, Kathmandu, Nepal from 2007 to 2013. In 2013, he moved to United States for his graduate studies at Florida Atlantic University (FAU). Currently he is actively involved in research in Medical Physics. His interest is in applied physics; specifically, the improvement of cancer treatment methods which is part of the degree requirement for his professional Masters’ in Medical Physics and Ph.D. He is currently a graduate Teaching Assistant in the Department of Physics at FAU.

Taindra Neupane was born on April 12, 1985 in Jhapa, Nepal. He received his MS in physics from Tribhuvan University, Nepal in 2012 and began further graduate studies at FAU in fall 2013 to pursue a PhD in physics. He’s also duel enrolled to complete his masters in medical physics as he pursues his PhD. Currently, he’s conducting cancer research using a radiation beam to create a small field in conjunction with the M6 CyberKnife at Lynn Cancer Institute of Boca Regional Hospital. Mr. Neupane has attended many conferences in Florida, with respect to cancer treatment via chemotherapy and radiation therapy and has been selected for a poster presentation of his research work at the 2017 American Association of Physicist in Medicine (AAPM) meeting in Colorado.

Kingsly Alec McConnell is a senior at Florida Atlantic University graduating with a degree in history and minor in Japanese. He the recipient of the Department of History’s 2017 Hugh W. Ripley Award for demonstrating research skills in Senior Seminar, and his research focuses on intersections of race, gender, and sexual orientation in the United States and abroad. Upon graduation this summer, he is attending University of Washington School of Law to study international human and civil rights law.

Nicole McRostie is a senior at the Harriet L. Wilkes Honors College pursuing a major in psychology. She works as a peer mentor for the Academy of Inclusion and is president and founder of the Psychology Club. Nicole has also worked in two psychology labs on six different research projects. She spends her summers in Chile where she volunteers at a low income school teaching English to all grades. She will continue her education in psychology by attending graduate school, since her ultimate goal is to become a psychology professor.
Dakota Merchant recently graduated May 2017, from the Charles E. Schmidt College of Science at Florida Atlantic University with a double major in Neuroscience & Behavior and Psychology. Dakota plans to pursue a Master’s degree in Mental Health Counseling before applying to Medical School to become a Psychiatrist.

Jared Miller is a senior in the Charles E. Schmidt College of Science at Florida Atlantic University, majoring in Mathematics. Jared plans to pursue a Ph.D. in either the Mathematics Sciences or Cryptography.

Bianca Bratkons is a senior in the Charles E. Schmidt College of Science at Florida Atlantic University, majoring in Mathematics.

Brian Labarre is a post graduate student in the Charles E. Schmidt College of Science at Florida Atlantic University, taking a range of classes within the Mathematics department.

Mesgana Hawando is a Ph.D. student in the Charles E. Schmidt College of Science at Florida Atlantic University. Mesagana aims to complete a Ph.D. at FAU within the Mathematical Sciences.

Jeffrey Stuart was born in Dallas, TX in 1989 and graduated from Lakehill Preparatory School in 2007. After graduation, he attended Goucher College in Maryland, Richland College in Texas, and finally transferred to Florida Atlantic University where he is currently a senior working towards a Bachelor’s Degree in English with a concentration in writing and rhetoric. After his internship in Summer 2017 is complete, he will have completed the required steps for his Certification in Professional and Technical Writing. After graduation, Jeffrey plans on a career in Copywriting or Content Creation.
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"I could either watch it happen or be a part of it."

- Elon Musk