

The Penn State McNair Journal

Summer 2016, Volume 21

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WELCOME

Since 1991, the Penn State McNair Scholars Program has enriched the lives of students at Penn State. The McNair Program holds a very special place in our lives, as well as in the lives of the faculty and staff who work with our students. This publication celebrates their achievements and we offer it to our readers with pride and pleasure.

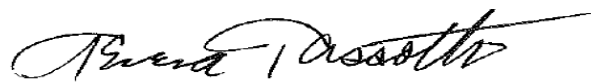
This is the twenty-first issue of the Penn State McNair Journal. We congratulate the Penn State McNair Scholars and their faculty research advisers! This journal presents the research conducted in the summer of 2016 by undergraduate students from Penn State, who are still enrolled in the Penn State McNair Scholars Program.

The articles within this journal represent many long hours of mutual satisfying work by the Scholars and their professors. The results of their research are published here and have also been presented at various research conferences around the country. We are especially proud to see how these students have grown as researchers and scholars. The hard work, dedication, and persistence required in producing new knowledge through research is most evident in these articles.

We very much appreciate the guidance, expertise, caring and patience of our fine group of Penn State faculty research advisers. For their ongoing support and assistance, we thank Eric Barron, President of Penn State University; Nicholas Jones, Executive Vice-President and Provost; Regina Vasilatos-Younken, Vice Provost for Graduate Education and Dean of the Graduate School; Michael Verderame, Senior Associate Dean; Suzanne Adair, Assistant Dean for Graduate Student Affairs, and Stephanie Danette Preston, Senior Director of the Office of Graduate Educational Equity Programs, the administrative home of the McNair Scholars Program.

We are also fortunate to have the support and encouragement of many faculty and staff members who have worked with our students as social mentors or who have presented workshops and seminars on the many aspects of graduate and faculty life. You give the most precious of gifts to our students – your time in volunteering to support, encourage and nurture our Scholars' hopes and dreams.

Lastly, we would like to acknowledge the work of three of our McNair scholars whose summer research is not included in this online publication. Their work is still ongoing and will be submitted to peer-reviewed professional journals in their fields for first consideration to be published. We applaud these scholars – Emily Cribas, Karina Cuevas-Mora and Quianna Miller. Their faculty research advisers and social mentors are included in this journal's acknowledgements section.



Project Director

TRIO PROGRAMS ON THE NATIONAL LEVEL

Since their establishment in the mid nineteen-sixties as part of Lyndon Johnson's War on Poverty Program, the federal TRIO Programs have attempted to provide educational opportunity and make dreams come true for those who have traditionally not been a part of the educational mainstream of American society. The TRIO programs are funded under Title IV of the Higher Education Act of 1965. While student financial aid programs help students overcome financial barriers to higher education, TRIO programs help students overcome class, social and cultural barriers to higher education. There are eight TRIO programs, which include the original three – Upward Bound, Talent Search and Student Support Services. The additional programs are Educational Opportunity Centers, Upward Bound Math & Science Centers, the Ronald E. McNair Post-Baccalaureate Achievement Program, Veterans Upward Bound, and a training program for TRIO staff. McNair programs are located at 156 institutions across the United States and Puerto Rico. The McNair Program is designed to prepare participants for doctoral studies through involvement in research and other scholarly activities.

TRIO PROGRAMS AT PENN STATE

The ten TRIO Programs at Penn State comprise six of the eight TRIO programs. There is the Educational Opportunity Center serving Philadelphia, two Talent Search Programs serving select western Pennsylvania school districts and the York City school district, the Ronald E. McNair Scholars Program serving the University Park campus, two Student Support Services Programs serving the Greater Allegheny and Wilkes-Barre campuses, the Upward Bound and Upward Bound Migrant Programs serving central and southeastern Pennsylvania select school districts, and the Upward Bound Math and Science Program serving select central and southeastern Pennsylvania school districts. These programs annually serve more than 6,000 students, from 6th graders through adults, all with clear potential for academic success. Altogether, the programs operate across select Penn State campuses and in communities across the state, often linking with middle schools, high schools, and community agencies. The programs focus on helping students overcome economic, social, and class barriers so that they can pursue education beyond high school.

MCNAIR SCHOLARS PROGRAM AT PENN STATE

Designed for low-income and first-generation college students, and students from groups underrepresented in graduate education, the McNair Scholars Program at Penn State encourages talented undergraduates to pursue doctoral degrees. The program works closely with these participants through their undergraduate career, encourages their entrance into graduate programs, and tracks their progress to successful completion of advanced degrees.

The goal of the McNair Program is to increase graduate degree attainment of students from the above-mentioned underrepresented segments of society. McNair Scholars are presented with opportunities to study and do research in the University's state-of-the-art facilities in order to hone those skills required for success in doctoral education. Through both academic year and summer program components, McNair Scholars are required to complete a series of steps that lead to their application and enrollment in a graduate program of their choice.

Since 1991, the McNair Scholars Program at Penn State has helped 288 students earn their baccalaureate degrees. Of these graduates, 245 (85 percent) have gone on to attend graduate school at institutions across the country and overseas; 59 graduates (26 percent) have earned their academic or professional doctorates; and 31 graduates also earned their master's degrees prior to the doctorate. Another 161 (66 percent) have now earned their master's degrees. Currently, there are 52 (21 percent) who are still enrolled in graduate programs. Among the institutions McNair alumni have attended or now attend are: Arizona State, Boston University, Columbia, Cornell, Harvard, Howard University, Indiana University, Iowa State, Johns Hopkins, New York University, Ohio State, Penn State, Purdue, Stanford, Temple, Texas A&M, University of California-Berkeley, University of California-Davis, University of California-Los Angeles, University of Chicago, University of Florida, University of Illinois-Urbana Champaign, University of Maryland-College Park, University of Michigan, University of North Carolina-Chapel Hill, University of Pennsylvania, University of Texas, University of Wisconsin, and Yale University, to name just a few.

Summer 2016 McNair Scholars and Program Staff



Penn State McNair scholars and program staff gather during the 2016 Penn State McNair-SROP Summer Research Symposium held July 24-25, 2016 at University Park, Pennsylvania.

ABOUT RONALD E. MCNAIR

Dr. Ronald Erwin McNair, the second African American to fly in space, was born on October 21, 1950, in Lake City, South Carolina. In 1971, he received a Bachelor of Science degree, magna cum laude, in physics from North Carolina A&T State University. He continued his education at the Massachusetts Institute of Technology (MIT) where, in 1976, he earned his Ph.D. in physics.



While at MIT, McNair performed some of the earliest development of chemical and high-pressure CO lasers. He went on to study laser physics at E'cole D'ete Theorique de Physique in Les Houches, France. He was well published and nationally known for his work in the field of laser physics through the Hughes Laboratory.

In 1978, McNair realized his dream of becoming an astronaut when he was selected from a pool of several thousand applicants to be included in the first class of thirty-five applicants for the space shuttle program. Ronald McNair and six other astronauts died on January 28, 1986 when the space shuttle *Challenger* exploded after launching from the Kennedy Space Center in Florida.



McNair was an accomplished saxophonist; held a sixth-degree, black belt in karate; and was the recipient of three honorary doctorates and a score of fellowships and commendations. He was married to the former Cheryl Moore and is the father of two children, Reginald Ervin and Joy Cheray. After his death, Congress approved funding to honor the memory of McNair by establishing the Ronald E. McNair Post-Baccalaureate Achievement Program, which became the sixth program funded under the TRIO Programs umbrella.

“Historians, who will write about McNair, the man, will discover that there was much more to him than his scholastics achievements. Friends who knew him, say he walked humbly and never boasted about his achievements. They say his commitments were to God, his family and to the youths he encouraged to succeed.” (Ebony, May 1986)

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Development of Immunosuppressed Drosophila for a Novel Screen to Identify Essential Proteins for Host-Pathogen Interaction

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Abstract

Diarrheal diseases are a major cause of death in children under the age of five around the world. A rise of antibiotic resistance has also been detected in bacteria that cause diarrheal diseases, and so to combat these diseases new drugs must be developed. We have made an immunosuppressed *Drosophila* strain to conduct a genetic screen to identify proteins in the intestinal epithelium that are necessary for host-pathogen interactions. This fly line contains less dual oxidase (DUOX) to reduce the production of reactive oxygen species, which ordinarily combats bacterial infections in the gut. In the screen we crossed the immunosuppressed line with flies containing various RNAi knockdown constructs targeting proteins found at the apical surface of epithelial cells. The survival of immunosuppressed flies containing the RNAi constructs will indicate that the knocked-down protein is necessary for infection. Future work can then be done to develop new drugs against these targets.

Introduction

Diarrheal diseases caused by bacteria are a major cause of illness and death globally. In 2010 an average of over 2,000 children under the age of five died from diarrheal diseases every day (Liu *et al.*, 2012). The developing world suffers more from these diseases due to lack of sanitation, malnutrition, and lack of proper medical care. Some diarrheal diseases are easily treated with proper hydration, but more serious cases need antibiotics (Guerrant *et al.*, 2001). Lack of proper medical training has led to the over-use of antibiotics in the developing world, which has led to the development of antibiotic resistance (Okeke *et al.*, 1999). It imperative that new non-antimicrobial drugs are developed to combat bacterial infections and limit the spread of antibiotic resistance. Our research searches for possible targets for non-antimicrobial drugs through the use of a genetic screen using the fruit fly *Drosophila melanogaster*.

Much is known about the interactions between bacteria that cause disease and the intestinal cells they infect. Some bacteria rely on similar cell functions to establish

infection, but each of them will infect different parts of the epithelial cells. *Escherichia coli* (*E. Coli*), *Salmonella*, and *Shigella* all rely on actin modulation to establish infection, but *E. coli* infects the microvilli, while *Salmonella* enters epithelial cells to establish infection (Dean, 2011). Knockdown of bacterial virulence factors have been done to determine their necessity for infection, but knockdown of epithelial cell proteins has not been tested to determine their necessity during infection.

The first interaction between bacteria and the cells they infect occurs at the microvilli on the apical surface of epithelial cells. These cells contain different proteins that determine cell polarity, shape, and aid in different cell processes. One of those proteins is β_{Heavy} -spectrin, which localizes to the apical surface of epithelial cells (Zarnescu and Thomas, 1999). β_{Heavy} -spectrin is found at the brush border where it crosslinks F-actin which in turn helps stabilize the microvilli (Bement and Mooseker, 1996).

Drosophila melanogaster is used as a model system to study intestinal infections because its host defenses are well known and can be easily manipulated. These defenses typically have analogs in mammals. For example, reactive oxygen species are produced as a defense against bacterial infections in mammals and *Drosophila* (Bae et al., 2010; Ha et al., 2005). Lack of the enzyme dual oxidase (Duox), which produces reactive oxygen species in *Drosophila*, causes flies to become more susceptible to bacterial infection since they lack the ability to effectively eliminate bacteria (Ha et al., 2005). Flies subjected to RNA interference (RNAi) towards Duox die within 5 days after oral infection with the plant pathogen *Pectobacterium carotovora carotovora* 15 (PCC15), while wild-type flies survive (Ha et al., 2005).

Pectobacterium carotovora carotovora 15 is a gram-negative bacterium that causes soft rotting in potatoes and other fruits by the production of pectinases (Barras et al., 1994). While most bacteria seem to pass through the fly without eliciting a response, PCC15 has been shown to induce an immune response and persist in the gut of larvae (Basset et al., 2000). Two bacterial genes have been found to allow for the persistence of PCC15 in the gut of flies: one is a regulator, Hor, and the other is the Erwinia Virulence Factor (Evf) (Basset et al., 2003). Evf is a transmembrane protein that if over expressed causes strong lethality in fly larvae (Muniz et al. 2007). Evf contains a palmitic acid moiety on the C-terminal end of the protein that allows it to bind to membranes of the gut cells and is necessary for infection (Quevillon-Cheruel et al., 2009)

To examine which proteins in the gut are necessary for bacterial infection we will be using RNAi knockdown of various proteins in the gut epithelium of *Drosophila*. A fly line containing an RNAi for dual oxidase will be crossed with flies containing homozygous copies of RNAi for proteins in epithelial cells. These flies will then be orally infected with PCC15 and monitored for survival. If more than 50% of the infected flies survive then the missing protein is essential for bacterial infection.

Methods

Fly Stocks

Flies were grown at 25°C on fly media composed of 0.82% agar, 12.94% sugar, 3.22% yeast, 6.12% cornmeal, 0.82% tegosept, and 0.18% propionic acid. An immunosuppressed fly line was created by combining the dual oxidase RNAi construct (CG3131) along with the driver da-Gal4, the Gal4 inhibitor Gal80, and the fluorescent marker tdTomato, and the marker balancer TM6 (daGal4, tdTomato, Duox^{RNAi}/ Gal80, TM6). To improve the immunosuppressed fly line a second daGal4 was added to the line by crossing it to BL55851.

Bacterial Strains

Pectobacterium (formerly *Erwinia*) *carotovora carotovora* 15 (PCC) was obtained from Dr. Timothy McNeillis (Plant Pathology, Penn State), and used in the infection experiments. The bacterium was grown on LB agar plates (1% tryptone, 0.5% yeast extract, 0.5% NaCl, 0.1% 1M NaOH, and 1.5% agar) and broth (1% tryptone, 0.5% yeast extract, 0.5% NaCl, and 0.1% 1M NaOH) at 28° C.

Infection Experiment

Adult flies were dehydrated for two hours before infection. After dehydration the flies were exposed to PCC15 at O.D.₆₀₀ 200, O.D.₆₀₀ 100, and O.D.₆₀₀ 50 re-suspended in 5% sterile sucrose on filter paper. The flies were exposed constantly to the bacteria. The filter paper containing the sucrose and bacteria were replaced every 24 hours with fresh bacteria at which point the viable count was determined each time.

Tail PCR

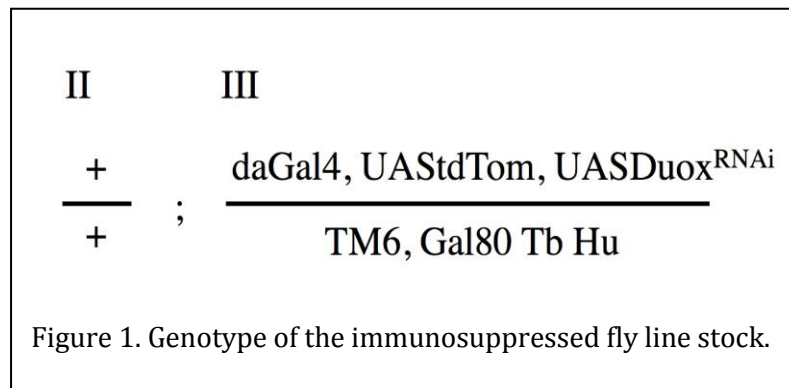
Tail PCR was used to identify the location of the daGal4 on the second chromosome and was performed, as described in Singer and Burke (2003). Tail PCR uses nested primers for the known region of the insert and arbitrary primers (AD primers) that recognize sections of DNA within the genome. The AD primers are a mix of primers that have different annealing temperatures, but will anneal to the same area producing one size band. The nested primers used provide specificity for the P-element and not any other sequence in the genome. The nested primers for the 5' end of the P-elements were 5'-CACCCAAGGCTCTGCTCCCACAAT-3', 5'-TACTCCAGTCACAGCTTTGCAGCA-3', and 5'-ACACAACCTTTCCTCTCAACAA-3'. The nested primers used for the 3' end of the P-element were 5'-ATTCAAACCCACGGACATGCTAAGG-3', 5'-ACAATCATATCGCTGTCTCACTCAG-3', and 5'-CGACACTCAGAATACTATTCTTTCAC-3'. The reverse primers used are described in Singer and Burke 2003. DNA was extracted from the BL 55851 line using standard procedures, and was quantified using a Nanodrop spectrophotometer. Samples were also analyzed using a pre-existing lab stock of DNA from the P-element free strain Oregon R

as a negative control. The sequence of this band was determined by the Huck Institute Genomics Core Facility and analyzed using the NCBI (National Center for Biotechnology information) Blast website.

Results

Development of an Immunosuppressed Fly Line

The reactive oxygen immune response of *Drosophila melanogaster* to bacteria was suppressed by the addition of dual oxidase RNAi (Duox^{RNAi}) to the third chromosome. Figure 1 illustrates the genetic makeup of the fly stock, which contains the following other genetic elements: (i) da-Gal4 used to express the Duox^{RNAi} throughout the fly; (ii) the fluorescent protein tdTomato, to allow easy differentiation between the immunosuppressed flies from the immunocompetent ones; and (iii) a tub-Gal80 construct to inhibit the action of Gal4, and therefore the expression of the Duox^{RNAi}, allowing the stock to remain healthy until it is used in a test cross.



Testing the Immunosuppressed Fly Line

The immunosuppressed fly line was crossed with *yw* wild-type flies to determine the dosage of bacteria that would be lethal to the immunosuppressed flies, but not the immunocompetent siblings. Bacterial dosage was determined by using cultures of different optical densities measured at a wavelength of 600nm (OD₆₀₀). Tested were cultures with an OD₆₀₀ of 12.5, 100, and 200. Figure 2B illustrates the survival rate following the oral infection by PCC15 with the corresponding OD₆₀₀. Ha *et al.* (2005) showed that flies lacking Duox died after five days when exposed to PCC15 at an OD₆₀₀ of 12.5. The oral infection with the immunosuppressed flies did not yield the same result. After six days of oral infection only 10% of the flies at OD₆₀₀ 12.5 had died (Figure 2B). In light of this result higher infection with higher OD₆₀₀ concentrations were also tried, with very similar results (Figure 2B). To improve the immunosuppression and obtain the result reported in Ha *et al.* (2005) we have added an extra da-Gal4. Since we have extra Gal4-dependent genetic elements compared to Ha *et al.* (2005), we hypothesized that there is not enough Gal4 to suppress the Duox effectively.

A

Immunosuppressed

II III

 $\frac{\text{daGal4}}{+}$; $\frac{\text{daGal4, UAS}^{\text{StdTom}}, \text{UAS}^{\text{Duox}}^{\text{RNAi}}}{+}$

Immunocompetent

II III

 $\frac{+}{\text{cyo}}$; $\frac{+}{\text{TM6, Gal80 Tb Hu}}$

B

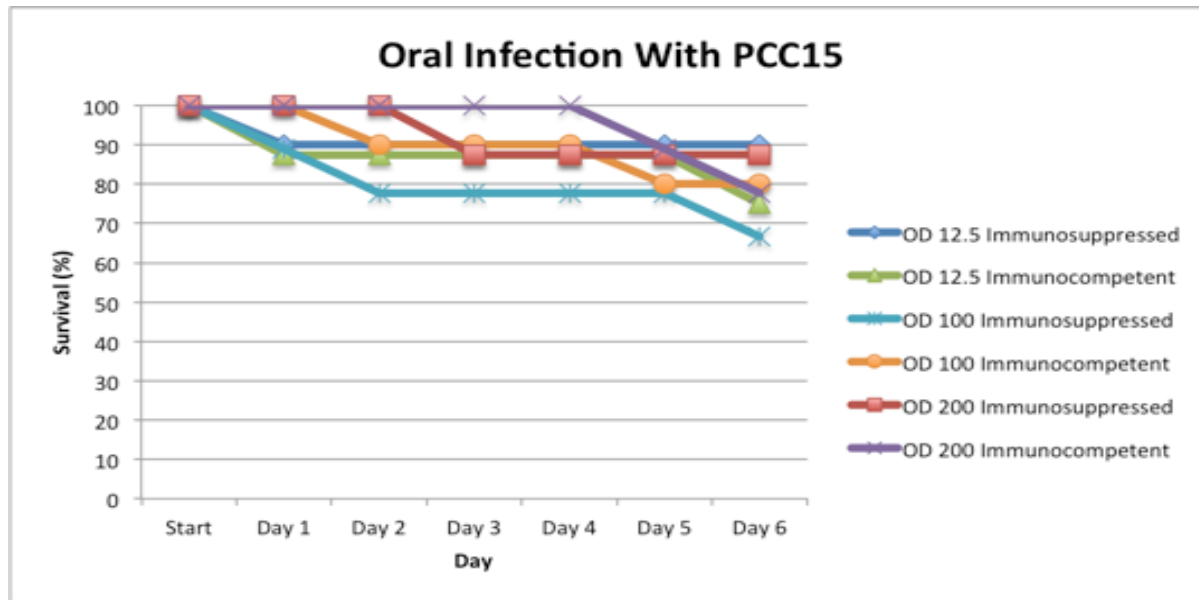


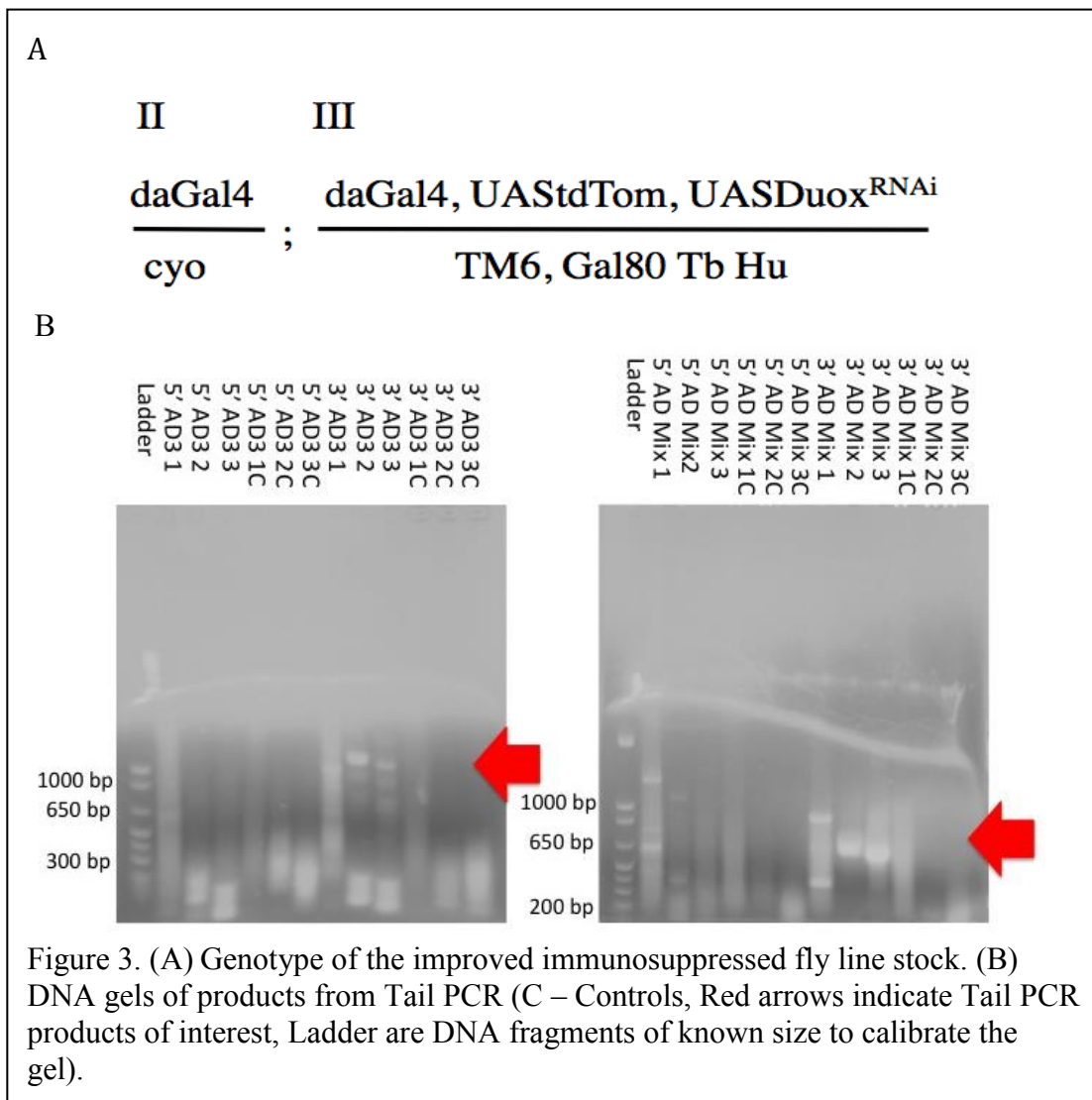
Figure 2. (A) Genotype of immunosuppressed flies and immunocompetent flies used to test lethal doses of PCC15. (B) Survival rates of immunosuppressed and immunocompetent flies after oral infection with PCC15 at a range of OD_{600} . Ten immunosuppressed and ten immunocompetent flies were tested in each trial

Improving the Immunosuppressed Fly Line

To improve the immunosuppressed fly line a second daGal4 was added on the second chromosome by crossing the first immunosuppressed fly line with the fly line BL55851, which contains a homozygous copy of da-Gal4 on the second chromosome. This addition would result in an increase in expression of Duox^{RNAi} and therefore more effectively reduce the expression of the Duox protein. Figure 3A illustrates the genotype of the new immunosuppressed fly line. Since da-Gal4 does not have a phenotype and the fly line contains many genetic elements an assay must be developed to determine whether the second da-Gal4 was successfully added. To do this we must first determine the exact molecular location of the da-Gal4 in the BL55851 line, and we decided to do this by using Tail PCR (Singer *et al.* 2003). Once the location is known we can easily create a specific PCR assay to screen the new line for the addition of the second daGal4.

Tail PCR works to capture the DNA adjacent to the da-Gal4 construct by using nested primers for the known region of the P-element and arbitrary primers (AD primers)

that recognize sections of DNA within the genome. The nested primers for the P-element used in Tail PCR will produce sequentially smaller products in each of the three PCR reactions, which make them easy to identify. The nested PCR primer also adds specificity to the reaction. The DNA gel shown in Figure 3B shows two likely positive results. The sequence of the band labeled 3' AD3 Mix (Figure 3B, lane 3' AD Mix 3) should correspond to the 3' end of the P-elements plus the flanking DNA in chromosome II. NCBI Blast analysis of the sequence indicated that, the P-element was located on the third chromosome, whereas the location of the da-Gal4 in the line BL55851 was reported to be in the second chromosome. It is not unheard of for P-element containing stocks to contain cryptic P-elements (Dr. Graham Thomas, personal communication), and it would appear that this is what has been uncovered. An initial attempt to analyze the bands in the AD3 samples (Figure 3., Lane 3' AD3 3) was unsuccessful, and so further experiments will need to be done to confirm the location of the da-Gal4 construct in the BL55851 line.



Discussion

Knockdown of Duox has been shown to be lethal in fruit flies when they are exposed to PCC15 (Ha *et al.* 2005). We developed an immunosuppressed fly line incorporating Duox^{RNAi} to examine which proteins in the gut are necessary for bacterial infection. While testing the immunosuppressed fly line with an oral infection of PCC15 we did not see the same lethality seen in that paper. To improve our line we added a second da-Gal4 driver by crossing the immunosuppressed fly line stock with a fly line containing a homozygous copy of a second da-Gal4 element on the second chromosome. Tail PCR was used to try and determine the location of the second da-Gal4, but sequencing indicated that the da-Gal4 line probably has a second P-element on the third chromosome that is confounding our analysis.

Once the location of the second da-Gal4 is confirmed we will use this knowledge to design a specific primer flanking the P-element in the genomic DNA of chromosome II. The combination of this primer with one in the da-Gal4 P-element will be unique, even in the context of all the other genetic elements in the new immunosuppressed line, and will provide definitive proof that it is indeed present. Following this determination, a genetic screen will be performed to examine the host-pathogen interaction (i.e. fly<-> PCC15). In this screen we plan to cross our newly developed fly line with other fly lines containing RNAi knockdown constructs for proteins at the apical surface of epithelial cells as well as for other proteins involved in signaling in this region. A positive result in the screen would be indicated by at least a 50% survival of the immunosuppressed flies containing the RNAi knockdown for the apical or signaling protein following bacterial infection. This result would indicate that the knockdown of that particular protein is essential for the bacteria to effectively infect the cells. A negative result would be indicated by near 100% death of the immunosuppressed flies containing the RNAi knockdown of the apical or signaling protein. This screen will provide insight into host-pathogen interaction and the development of new drugs targeting the identified proteins.

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Interrupted Subjectivity: An Investigation into the Meaning of Racialized Embodiment

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Abstract

The invention, production, and operation of race are entangled with the processes of subject formation. One of its most evident effects is the degradation of the subjectivity of those who are submitted to its conditions. The aim of this essay is to investigate both the production and meaning of race, especially as it has been either passively neglected or deliberately addressed within contemporary philosophy. This meaning will be discovered by an initial investigation into problems of embodiment found in Rene Descartes *Meditations on First Philosophy*. Then, further exploration of figures in modern phenomenology, namely Edmund Husserl, Maurice Merleau-Ponty, and Simone de Beauvoir, will allow us to deepen our understanding of differential forms of embodiment, specifically, gender and racialized bodies. In the last section, a turn to Cornel West's genealogy, George Yancy's phenomenology and Ta-Nehisi Coates's political phenomenology, will lead to the latest development in the analysis of racialized embodiment, which in this essay are profiled as a form of "interrupted subjectivity."

Introduction

The aim of this essay is to investigate the meaning of race, especially as it has been either glaringly neglected or deliberately addressed within contemporary philosophy. I will follow the following trajectory: First, I will start by exploring some issues of embodiment in Descartes, the founding father of modern philosophy. Descartes is important because in his famous "cogito ergo sum" we can discover what could be called the "Cartesian Ruse," by means of which embodiment is both assumed and concealed. This is relevant to questions of race, which is both presupposed and effaced by the modern subject. Then, I will proceed to explore some figures in modern phenomenology, specifically Edmund Husserl, Merleau-Ponty and Simone de Beauvoir, in order to understand the meaning of the experience for different bodies. More concretely, I will explore the implications of racializing stigmatization, how it disrupts subjectivity by disrupting the subject's sense of their own embodiment, and the consequences of the disrupted subjectivity for social agency. In a third step, I will turn to genealogy, as is exemplified in the works of Cornel West and George Yancy. Additionally, I will explore the recent work of Ta-Nehisi Coates, which we could call a form of "political phenomenology" that in my analysis bridges phenomenology and genealogy.

The philosophical steps of these investigations I undertake on the meaning of racializing embodiment are the following: I move from Descartes to phenomenology since the latter finds its roots in René Descartes' famous *Cogito*, in which the subject gives itself to itself by the mere act of thinking (cogitation). Going beyond this individualistic, putatively disembodied, ahistorical subject, phenomenology grounds the subject in a body, which is still not in history or society, and explores how the world manifests itself to this embodied subject. Such manifestations further shape the way a subject arrives to bodily awareness, practices embodied action, and engages in social activity. I argue, however, that phenomenology fails to recognize the construction of consciousness within a paradigm of dehistoricized and delocalized subjectivity, thus ignoring the way society not only constructs the conditions for their own embodiment, but also the way the worlds are constructed instead of discovered through these subjects. Thus, I turn to genealogy in order to examine the construction of subjectivities and forms of agency, and how the constructed subjects and agents interact within a historically contingent matrix of intelligibility; the worlds of what can and cannot be known, experienced, and lived by embodied agents. In order to discover new worlds or matrixes that open up new horizons of experience and agency, the subject must re-construct itself in order to unfold itself into this new world. For genealogists, knowing does not occur first through either experience or cognition, rather modes of embodiment and agency must be first constructed which enable these modes of experience and cognition.

The core questions that motivate my investigation then are: How does this world of constructed subjects within their respective matrixes of intelligibility affect subjects that are exposed to racism, in fact, that are constituted as racialized subjects? Does the existence of racism prompt them to “switch” from one subjectivity to another depending on which matrix to which they are exposed? How does this affect their embodiment? In which way do subjects become objects of race in the contemporary world, and how does it largely disrupt their subjectivity, which consequently limits how a subject embodies, comports, and socializes itself?

The Invention of the Cogito

To begin an examination of the subject, we must begin with René Descartes. In his famous ‘*Cogito ergo sum*’ (I think, therefore, I am)--, which is to be found in *Meditations on First Philosophy* (1641), Descartes gives birth to modern philosophy by articulating the subject in a new way. First, the subject is completely reliant on cogitation as a means of knowledge. Any information gathered through the body, or what he calls *res extensa* –*extended matter*--, such as sensory perception or bodily experience, can ultimately be doubted by the cogito. Descartes explains, “For I also judged that to have...the power of sensing or cogitating, in no way pertains to the body” (Descartes, 103). The body’s capacity to gather information from the world is doubted within the Cartesian Subject. However, this doubt does not end with the simple denial of extension; it also conditions the individualism of the “I”. What is radically new in Descartes’ view of the subject is its birthing itself through doubt.

The driving force behind Descartes method is the use of radical doubt to uncover certain truths. This doubt not only constructs how the subject thinks, but it also ensures the ultimate individualistic authority of the subject. By doubting all things that it cannot cogitate with clarity and distinctness, the subject gives itself to itself through the act of thinking. Concretely, “‘I am, I exist’ is necessarily true, as often as it is uttered by me or conceived by the mind” (101). Existence is not contingent on the possession of a body, nor does it find meaning from co-

existing with others. Rather, the cogitating “I” is the stem of existence, and the subject has ultimate authority. This “I” is sovereign, self-giving, independent, and ultimately, solipsistic.

Furthermore, Descartes worked to find a way in which the existence of an infinite, perfect being (God) can be found through ideas rather than through faith in his meditations. This may seem like a useful conclusion to proponents that posit the existence of God. However, this system corrodes the foundations and operation of faith, guides the Cartesian subject to solipsism, and further illustrates the absolute primacy of the Cartesian subject. Descartes qualifies this, “And from this one thing [God] – that there would be such an idea in me, or that I would exist as one having this idea – I so manifestly conclude that God also exists...” (151). So, two things the Cartesian subject can be certain of are the existence of himself and the existence of God, which comes from himself. Although it may seem that the subject is setting God up as an independent entity, God is essentially found through the subject, rather than God revealing himself to the subject. First comes the thinking “I,” then comes the discernment of the idea of God. This causes the practice of faith to become superfluous since the subject is the sole authority in acquiring knowledge. This act of discovering the only thing the subject can be certain of besides itself also points to an extreme solipsism; not only can the subject be sure of itself, but it also is the only means of acquiring knowledge and qualifying certain ideas. The subject can “be” and “think” independently. God becomes a superfluous idea.

This ‘cogito ergo sum’--I think, therefore, I am-- is essentially, I would claim, a ruse of the subject. Within the Cogito, the subject presupposes that the “I” is able to be the sole verification of its self-certainty. This “I” can only trust its act of thinking, and staunchly denies its bodily extension. Descartes is clear about this: “And I have indeed a much more distinct idea of the human mind, in so far as it is a cogitating thing – not extended in length, breadth and depth, and not having anything else from body - , than I have a distinct idea of any corporeal thing” (151). Yet, this presupposition is essentially a ‘trick’ of the mind. Clearly, in order to cogitate, one must be in a body to be grounded in existence. The subject within the Cogito can only know itself through embodiment. There is no “I” without a body or a substance through which to think. This denial of the dependence of cogitation on the body may seem trivial, but it leads to the objectification of the subject’s own body, which is always doubted. If the subject is able to objectify its own body through doubt, how will it handle other bodies? If it can ‘bracket’ its own embodiment, how can the cogito that is imprisoned within its own cogitation ever recognize other minds, when these minds are given to us firstly through their embodied existence? There is no other that is not an other body, first and foremost. However, if this other is a body, and bodies are to be doubted, then Descartes is implicitly saying that other “minds” or “Is” remains beyond cogitation.

Descartes deploys his Cartesian Ruse most explicitly in his example of the melting beeswax. He observes the beeswax, fresh from the honeycomb, and gathers information based on its scent, texture, consistency, and appearance. This technique is a precursor to ‘eidetic reduction’ used in phenomenology, which makes use of bracketing the different qualities of an object in order to arrive at some certain truth. Yet, as soon as the beeswax is exposed to an open flame, the qualities melt into a transformed ambiguity. The beeswax has melted, lost its sense, and is hot to the touch, yet it remains, or so it seems, the same piece of wax. How may the meditator know that the melted beeswax is the same beeswax that was just solid? Simply, “...The perception of the wax is not vision, not taction and not imagination, nor has it ever been...but rather is the perception of the inspection of the mind alone...” (113). Although cognition is needed to synthesize the condition of the beeswax both before and after the event of melting, it is not the

only operation necessary to understand the process of the melting beeswax. The subject must be in a body in order to utilize sensory perception, which then gathers information about the beeswax and its qualities. However, it is through an innate cohesion between the senses, the information gathered through perception, and the force of cogitation, which forms this knowledge of the melting beeswax. Although Descartes is especially interested in the force of cognition, this example reveals that sensory experience and cognition must cohere to access knowledge.

Throughout his meditations, Descartes forms a peculiar subject that finds its individualism, solipsism, and disinterested objectification using radical doubt, the legitimacy of innate ideas, and the ultimate authority of cogitation. Radical doubt separates the subject from a body; the subject can only be sure of the Cogito, “I think; therefore, I am” which gives the subject individualistic certainty. The Cogito is given to the “I” by its activity, and, at the same time, the subject also cognizes an idea of God – infinite perfection that has endowed the subject with an idea of Him. However, it is important to note that God is not *revealing* himself to the subject, but rather the subject is finding this idea within a record of other ideas. These ideas vary in clarity and distinctness, but the two clearest and most distinct ideas of the subject are that of itself and that of God. The subject comes to know things only through its own cognition. Bodily doubt coupled with individualistic and solipsistic characteristics condition the subject to be one that objectifies other subjects. Not only is the subject able to suspend its body from itself through doubt, this doubt also allows the subject to objectify the body. The body is less known than the mind. Since doubt of extension grants the subject the power to objectify its own body, then how will the subject approach other bodies? It is fair to assume that those other bodies will be objectified, but in what way? Will the subject be disinterested in others bodies, as it is in its own body, or will the subject invest in other bodies as objects, rather than subjects, as it does with the beeswax?

The Body of the World

Edmund Husserl addresses the problems of embodiment found in Descartes *Meditations on First Philosophy* in his own work *Cartesian Meditations*, which is named as such in order to honor Descartes as the precursor to the phenomenological method. According to Husserl, Descartes sparked the phenomenological method by using a primitive version of the eidetic reduction while meditating on melting beeswax. In this *Meditation*, Descartes takes note of the beeswax’s different characteristics in order to arrive at a certain truth. Although the title of the work pays homage to Descartes, Husserl shows through his own meditations that Descartes method in his meditations was not thorough enough and aims to solve the paradoxes and problems found within Descartes individualistic, solipsistic, and disinterested Cogito.

The Cogito that appears as complete in its self-giveness is nothing but an illusion; the Cogito is much more active than simple cogitation. When the subject asserts, “I think, therefore, I am” it is not simply existing according to cognition, but rather, the subject is practicing a process of synthesis. Husserl explains, “The ego [subject] is himself existent for himself in continuous evidence; thus, in himself, he is continuously constituting himself as existing. Heretofore we have touched...the flowing cogito. The ego grasps himself not only as a flowing life, but also as I, who lives this and that subjective process, who lives through this and that cogito, as the same “I” (Husserl 66). By conjoining the acts of “thinking” and “being”, the subject is constantly synthesizing its very being. The subject tries to get ahead of itself by habituating its being in its

act of affirming “I am”, and at the same time is apprehending itself by its “I think.” This disjoint between the simultaneous synthesis and capture of the subject prevents the subject from being one, and thus renders it as a divided entity. This divided subject is caught up in the process of always trying to precede and predicate itself. The subject is not itself; it is becoming. The subject is sustained in a ceaseless process of synthesizing self-giveness.

Not only does Husserl’s Cogito entail the synthesis of the subject as a predication of being and the grounding of thinking, but this Cogito also presupposes a situated subject, a subject that occupies a distinct location in space and time. The Cogito is a situation, one that manifests itself as a space for the subject – a realm for its existence.—or rather, a subject of a given space. More clearly, “When I apperceive myself as a natural man, I have already apperceived the spatial world and construed myself as in space, where I already have an Outside Me” (83). Within the Cogito, “I am” not only establishes the specificity of the Subject as an “I” as such, but it also assumes there must be other things that are not “I”. These things must be part of a “world” where both “I” and “things” exist simultaneously. Thus, as the ego gives itself to itself in the Cogito, it is also giving itself to itself in a *world*. There is no activity of cogitation that does not presuppose the world; “I” and “world” are given simultaneously.

As the subject within the Cogito assumes itself as an “I” opposed to an “other” when synthesizing itself as itself, the “other” is outside and opposite to the interiority of the subject’s cogito. The interiority of the cogito, however, presupposes space, that is, it must be given within space. The process of habituation as a consequence of the subject’s constant synthesis also reveals the need for time as well as space for the subject. Both time and space give the ego a place and an occasion, a here and a now, which allow for cogitation. Time and space motivate the “I think” to continue cognition and fix the “I am” within a situation. The cogito prompts the ego to synthesize itself as “I” in the present moment, in the ‘here-ness’ of the cogito’s synthesizing itself, as well as consider what the “I” is.

The tension generated by the division within the subject, as well as the implicit existence of others, space, and time begins to remove the subject from the individualism found within Descartes’ cogito. Husserl answers to the solipsism and disinterest found in Descartes’ Method though the existence of the other as found through what he refers to as a “Transcendental Clue”. Concretely, “...my "transcendental clue" is the experienced Other, given to me in straightforward consciousness and as I immerse myself in examining the noematic-ontic content belonging to him (purely as correlate of my cogito, the particular structure of which is yet to be uncovered)” (90-91). This clue begins with the self-disruption or division of the cogito. The Cogito is already an ‘other’ to itself. Therefore, to be itself, it must posit what is not itself. A revised Cogito through this transcendental clue could be “I am because I am not that other”.

If the subject can find itself by not being the “other”, then the completion of this clue is revealed through the experience and cognition of the “other” through the condition of one’s own cogito. Others exist as “world objects” in respect to tangible things existing in the world as a physicality. They also exist as “subjects for this world” in respect to the capacity to experience the world and even other egos. Being a “subject for this world” permits individual egos to explicate one another, thus, finding one another.

The Transcendental Clue begins to remove the subject from its solipsism and disinterest by making a case for the other through the transcendence of the subject. Now, the subject is with and shares a world with others. Even in the attempt to disengage from the world and others, the subject finds itself bound to its situation:

“In the natural, the world-accepting attitude, I find differentiated and contrasted: myself and others. If I “abstract” from others, I “alone” remain. But such abstraction is not radical; such aloneness in no respect alters the natural world-sense, ‘experienceable by everyone’... which attaches to the naturally understood Ego and would not be lost, even if a universal plague had left only me” (92-93).

Even in the attempt to isolate itself, the subject always remains in a space with others due to the fact that it recognizes its very “otherness” in relation to other egos. This also points to an important feature of the world itself. The world is shared by a host of physical objects and synthesizing subjects; thus the world is engaged in a synthesizing of its own. The withdrawal of an individual would not stop this synthesis or the potential experience for others.

This subject, although an individual in its own right, is no longer an absolute individual. On one hand, the subject is synthesizing its own being, and on the other hand, the Transcendental Clue involves the “other” as a means of self-definition for the subject. However, the subject now detaches from its prior disinterest of others within Descartes’ method. Husserl explains: “That my own essence can be at all contrasted for me with something else, or that I (who am I) can become aware of someone else (who is not I but someone other than I), presupposes that not all my own modes of consciousness are modes of my self-consciousness” (105). The subject is thrown into a time and a space with other subjects and comes to know them through experience and cognition. The subject replaces its doubt with synthesis, both internally and when being with the other, and thus becomes interested in the world of others it inhabits.

This new interest in the world and others is not conditioned by the subject itself. More clearly, pure cognition and dependence on subjective ideas are no longer plausible sources for knowledge. Instead, interaction with the world and others becomes more essential:

“The fact of experience of something alien (something that is not I), is present as experience of an objective world and others in it (other Ego); and an important result of the ownness-reduction performed on these experiences was that it brought out a substratum in which a reduced ‘world’ shows itself, as an “immanent transcendency” (106).

The world does not exist for the individual, but is rather shared by a host of individuals, giving it its own transcendence. It is occupied by a host of subjects, each practicing their own Cogitos; the world is ultimately the multiplicity of subjective synthesis. Furthermore, the world is occupied by physical objects and otherwise governed by time and space, which reveals its immanence. Then, we have the following interesting conclusion. If the cogito is a ceaseless process of synthesis, and there is no cogito without a world and others in it, and this world is itself a product of an accord among many cogitation, then the world itself is discovered and synthesized. The world also is not one, but many, and it is not given at once. The world itself becomes a task.

How do subjects then interact with each other in this world? In a community, where certain roles are ascribed and practiced as such: “...an Ego-community, which includes me, becomes constituted (in my sphere of ownness, naturally) as a community of Egos existing with each other and for each other – ultimately a community of monads, which, moreover (in its communalized intentionally) constitutes the one identical world. (107). This community of egos constructs the world in which the individual ego exists, and we identify certain objects and groups through objectification. Through this, a collective, transcendental “I” is formed throughout the egos in order to construct a like-world in which the egos share like-experiences.

Being a Body/Having A Body

So far, we have surveyed how the Cogito has been constructed in two vastly different ways according to Descartes' method and Husserl's phenomenology. Although Husserl's phenomenology answers to the issues of solipsism, individualism, and subjective disinterest that plagued Descartes' version of the subject, Husserl's phenomenology presents issues of its own, namely, the subject's apparent lack of a body. Husserl places the subject in a world guided by time and space with other subjects and other objects, all of which are available for interaction; yet, he makes no effort to place the subject in a physical body. The cogito that is given with the world is strangely disembodied. It is the fleshiness of the cogito that Merleau-Ponty will personify. This embodied subject is explored in Maurice Merleau-Ponty's *Phenomenology of Perception*, which investigates the way the world manifests, is lived, and experienced by an embodied subject.

The Cogito exists in its original form, "I think, therefore I am" in Descartes *Meditations On First Philosophy*. This cogito assumes the form of a singular existence, and consequently it harbors a degree of individualism and solipsism. This singular existence is solidified in the self-giveness of the Cogito. This means that the subject gives itself to itself through cognition. This self-giveness is so dominant that the "I" in this Cogito also possesses a deep distrust of its own extension and sense perception. Knowledge, therefore, is only originated through the subject itself.

Husserl departs from this individualism by placing the subject in a world with others. A revised Cogito within his system could be "I am because I am already an "other" to myself". This self-otherness, or self-alienation begins with his transcendental clue, the intuition of an "other". For a subject to be itself, it must already possess an intuition of the "other", which leads the subject to consider its own otherness. Thus, being is being with others, who dwell in their own self-otherness, while "I" dwell in my self-otherness to my subject.

Instead of being solely concerned with its own individual cognition, the subject, or "I" in Husserl's Cogito, is in constant synthesis with itself and with its world. For Husserl, the "I" is its situation, its "circumstances." Husserl argues that there is no "I" that is not in time and space. This, of course, is the world, where other "I"s and other intentional objects exist. More importantly, this world is intersubjectively constituted, which is to say there is no world for the "I" alone. The world only exists because there is a community of "I"s that synthesizes the world. The world partially belongs to the "I", if at all, and this belonging must be confirmed by the others.

However, this "I", or subject, still is not yet a body. Merleau-Ponty responds to this lack with subjective embodiment; his Cogito could be revised as "I am because I am in-the-world". He grounds the "I" on the machinations of the world through the body; there is no world without our embodied existence. He claims that our body is our "vehicle" for worldly existence, but this comparison cannot be understood literally—the body is not simply a vehicle, like a taxi you get on and get off when you are done with your trip. Using the term "vehicle" suggests separation, as if the subject could take on and take off its body when it wills to be in or out of the world. This is not what Merleau-Ponty means. Rather, for him the body is in a dynamic relationship with the world, and the medium through which the subject experiences the world. We are not in the world by being in a body; we are in the world through **being** a body. We are riveted to the world by the quivering of the flesh. The world is our flesh; or rather, the flesh is our being in the world. We are with others, with the world itself, and with ourselves by being embodied. Embodiment,

however, is relational. We are our bodies by how the world touches are. Our bodies are the world and others touching us through our being with each other. The flesh of the world is the touch of others. We cannot be in the world without this touching, this ceaseless contact of bodies.

How do bodies interact with the world? Merleau-Ponty explores this problem using the phenomena of the “phantom limb” to describe the way bodies are conditioned by being in the world, and assert their being in a certain way. More concretely, he explains: “This phenomenon, distorted equally by physiological and psychological explanations, is however, understood in the perspective of being-in-the-world...I am committed to a certain physical and inter-human world...” (*Phenomenology of Perception*, 94). In Husserl’s *Cartesian Meditations*, the “I” is in a constant “catching up” with itself, asserting its being while also synthesizing its being, and never truly **being**. Likewise, the sensation of phantom limb shows that we are also in constant synthesizing of our bodies through a more extended form of relationality. For Merleau-Ponty, the “I” is more than an epistemic machine. The world is constantly constituting the “I” to view the world in a certain way, and with this outer-constitution, the “I” works double-time to rewire itself according to the messages sent by the world. The inner subject is involved in a web of relationships with the world, and when the body itself is damaged, it still attempts to perform as it did before the event of damage. This persistence of a “standard” bodily performance further reveals that we understand ourselves and our world not through cognition, but through the edge of our flesh. There is no “I” without the body.

It is clear that the subject’s sense of itself is inseparable from its body, but what about the actions of the subject? Likewise, the subject performs its intentionality in the world in a way, which it cannot be separated from the subject’s being. Subjects, in a way, are their own actions. This makes the actions of others legible to the subject, and the subject is able to compare the actions of the other with its own actions. Merleau-Ponty makes an interesting comparison between the expression of intentionality and works of art:

“A novel, poem, picture or musical work is individuals, that is, being in which the expression is indistinguishable from the thing expressed, their meaning, accessible only through direct contact, being radiated with no change of their temporal and spatial situation. It is in this sense that our body is comparable to a work of art. It is a nexus of living meanings, not the law for a certain number of covariant terms.” (175)

Just as subjectivity cannot be separated from a body, intentionality cannot be separated from being. Thus, subjects are both expressive and expressed, meaning that they can perpetuate their own intentions by their actions, yet these actions are also legible to others. Just as an artist shows her vision in a painting, we share our being and intentionality through our actions.

The Hierarchy of Being for Others

Through the phenomenological investigations of Husserl and Merleau-Ponty, we have arrived at a version of the subject that is grounded in a world and a body. However, we are left with scant clues about how the subject is conditioned by the world and the “others” with whom it interacts. Simone De Beauvoir takes a departure from Husserl, who focuses on the self-estrangement of the Cogito, and from Merleau-Ponty’s focus on the flesh’s unification with the body by examining the situation of a gendered body.

She conducts this examination by enacting the themes within existentialism developed jointly with Jean Paul Sartre. Beauvoir works with these fundamental pillars to existentialist analytics: first, “Existence Precedes Essence.” This means that we are our freedom, and become subjects

by choosing our freedom. Although this subjectively selected freedom may seem like a route back to Cartesian Solipsism, this freedom does not operate independently according to the pure will of a subject. The freedom of any given subject needs the freedom of the others in order to constitute its own subjectivity as freedom; when we choose ourselves, we choose it within the realm of the other's freedom. The second existentialist pillar deals with the "Bad Faith," which is the term given to the refusal to acknowledge the other's freedom, which in turn results in a failure to acknowledge one's subjective freedom. Lastly, "We are God's Useless Passion"; even if there would be a God, he would not prescribe our freedom for us. We would still possess the responsibility of having to be our own freedom – we are metaphysically bound to it.

With these existentialist guides enacted, Beauvoir accounts for how one's freedom (or lack thereof) shapes them into being a woman through the participation of the **construction** of her own freedom by the apparatus of nature and culture. The subject-as-woman is consumed in a "pageantry of gender", which she learns to perform, enact, and stage. Beauvoir asserts, "One is not born, but rather, becomes a woman" (Beauvoir, 267). The woman, then, is a role the subject assumes rather than an *a priori* condition of existence.

In the female performance of gender, the subject-as-woman generally is staged for her other (husband, children, family, other women, etc.). Her performance is for the sake of somebody else, and she finds personal accomplishment in this performance. What motivates this performance and legitimizes this feeling of accomplishment? Not from the subject coming to know it through its own cognition as found in Descartes, not subjective synthesis as stated in Husserl, not even through the edge of their flesh as posited by Merleau-Ponty, but rather comes into the subject through social pressure. There is a sociality, and thus historicity, of this subject's embodiment. Embodiment is also the cite for the sedimentation and accumulation of history.

The superficial aspect of this performance of the feminine requires the subject-as-woman to have a natural embodiment with artificial amendments in order to fit societal expectations, or, the male gaze. Beauvoir claims that woman is "...changed into a doll of living flesh" (501) while staging her gender. These contrasting characteristics highlight significant contrast between the shining plastic of the doll and the raw humanity of the flesh, pointing to the tension between culture and nature for the situation of the subject-as-woman. Her flesh becomes plastic in the performance of her gender; her flesh is colonized by the social via the male gaze. This colonization becomes a type of voodoo of gender performance and the societal expectation impressed upon the subject-as-woman.

Clearly, this performance is operating superficially. The woman does not display her femininity through her projects and actions. How does this show proceed? It proceeds through fashion, which acts as the colonization of female flesh by a male patriarchy. An exploration into objects of femininity will animate this performance, which advocates for the aesthetic value of female bodies, while constraining their own bodily freedom.

Consider the corset, which epitomizes feminine constraint within her gender performance. The corset squeezes and shapes the female body into a silhouette of male desire. She is bound into having a taught waist and bountiful hips as the comfort of her embodiment is disregarded – it becomes 'second' to her feminine appearance.

Let us compare it with the wearing of high heels. A woman's climbing up onto high heels situates the subject-as-woman in a precarious norm of immobility and pivots her to the male gaze. In contrast, men possess the privilege to be firmly planted on the ground in functional footwear that encourages his mobility and projects. Women are subjected to a hazardous situation in which they are always teetering. However, this teetering does not go without an

aesthetic 'benefit'. High heels tense the leg muscles artificially, as women are not expected to have very strong calves naturally, making them shapely and desirable. Such a display of the leg muscles remains unseen and unappreciated by the woman as she wears them, and operates entirely for the male gaze. She is a show. High heels also activate a directional power by accentuating the buttocks, which turns attention to her posterior as opposed to the front of her body, her gaze or her face. Again, her nature is being colonized by culture, as the focal point of her subject is not found in her intentions or projects, but rather found in her status as a perpetual sex object. She is not subject – she is show.

Such as the corset is the epitome of feminine constraints, make-up is the epitome of the distrust the subject-as-woman attaches to her own nature. Cosmetics work either to enhance the more aesthetically pleasing portion of the natural face, or to minimize what are qualified as "imperfections". They work to translate nature into something that is better than nature. The woman cannot trust her natural face, and thus must construct a mask for the world. This mask of nature naturalizes gender into a dual function: there exists a natural male form, which prompts no "need" for cosmetic intervention and denaturalizes the female form, which needs cosmetic and hygienic intervention. The natural female form cannot be trusted; it must be manipulated into something pleasant.

These examples help highlight the conditions of womanhood, which are laden with contradictory restraints. On one hand, the woman ought to be natural, and beauty should not be something in which she strains to perform. Yet, on the other hand, women are also encouraged to improve their natural selves. Advertisements implore women to improve their imperfections while also embracing their natural beauty; in this way, women either live a lacking nature or are hyper natural. She exists in this contradiction: "Through adornment... woman allies herself to nature while bringing to nature the need for artifice..." (498). Woman is in a constant synthesis of her physical condition, always both apprehending and extending it. It may seem that the subject-as-woman holds a degree of control over this embodiment, but it is still constricted to and guided by the male gaze.

Aside from aesthetic availability and the will to please through adornment, femininity is dominated by a subjective availability. As she "...delights with the display...of her own appearance", "her husband and children do not notice" (498), which points to the lack of reciprocity of her subject. Her efforts, although consistent, are not worth recognition. Thus, becoming woman is becoming available for someone else. Beauvoir will contribute this phenomenon to Sartre's modes of being; in itself and for itself, she adds: "before for others". Sartre's existentialism posits that "existence precedes essence," and that the subject is its own freedom. However, de Beauvoir argues that gender disallows this, and instead women passively perform for the male gaze.

Clearly, the subject-as-women exists in a situation that contrasts her against the 'natural', 'rational' and 'independent' male. She is the "Second" sex, but what does it mean to be "second"? Surely, the existence of the "second" assumes the existence of the "first". This means that the "second" is the "other" of the first; it is not the same thing as the thing the "first" is. The "second", in this way, may be subordinate to the "first", an existential afterthought of the "first", and spatially behind the "first". Yet, we may also imagine that the "second" may be the completion of the "first". The mere existence of a "second" may point to the insufficiency of the "first", the inability of the "first's" survival without the "second". One may question the condition of the "first" rather than the presupposed inferiority of the "second". If the "second" is

assumed inferior, is it through a true mark of inferiority, or through the paranoia of the “first”. Must the relationship between “first” and “second” mark a concrete “betterness” of the “first”?

From Phenomenology to Genealogy

Now, a turn to more modern genealogies will provide a clearer image of racism. First, the relationship between genealogy and phenomenology must be clarified in order to understand how both work together to reveal some truth about racism. Specifically, what does genealogy have to do with phenomenology?

To recall, phenomenology initially worked to analyze Rene Descartes’ *cogito ergo sum*, which formed a problematic subject. Specifically, this subject gives itself to itself by an act of its own thinking. This quality consequently conditions the subject to be individualistic, solipsistic, and both distrustful and disinterested of its own bodily extension. However, Descartes is able to initiate the phenomenological spirit through his examination of the melting beeswax. In this example, he makes use of the eidetic method, a type of phenomenological bracketing, in which he named the characteristics of the wax in order to arrive at an essential truth about the substance.

Both Descartes’ innovation of the beeswax and problems of embodiment are addressed in Edmund Husserl’s *Cartesian Meditations*. The inclusion of Descartes’ name in Husserl’s work shows Husserl’s respect for his predecessor, but Husserl still analyzes Descartes method. The *Cartesian Meditations* corrects the subject’s former individualism and solipsism by positing that the subject finds itself through synthesis, which leads to the existence of the other. Since the subject is able to find the other, both exist in the same time and space – the world, which is constantly synthesized by a community of subjects.

Still, this subject is not yet embodied. The radical embodiment of the subject is achieved in Maurice Merleau-Ponty’s *Phenomenology of Perception*. This newly embodied subject has a complex relationship with the world; the subject is now a body, practices intentionality, and becomes conditioned by worldly interactions. Most significantly, Merleau-Ponty’s example of the phantom limb proves the way in which subjects absorb an image of a “standard” body; even in the absence of a limb, the subject still *feels* its presence, and is eternally connected to the idea of a standard subject.

This ‘standard’ subject is the subject explored by Descartes, Husserl, and Merleau-Ponty, meaning, this subject is not an “other”. All three do little to acknowledge gendered or racialized subjects; Simone De Beauvoir explores this “other” subject in *The Second Sex*, which explicates the situation of the subject-as-woman. In this explanation, De Beauvoir makes the existential claim that one becomes a woman, rather than essentially being a woman. One becomes a woman by displaying a pageantry of gender, in which the woman manipulates her own body in order to adhere to societal expectations. Furthermore, De Beauvoir reveals woman as a subject *for others*, meaning that she uses her own existential freedom for the benefit for others.

Although De Beauvoir makes an important stride to examine the “other”, she as well as Husserl, and Merleau-Ponty all ignore the value of history as a condition of the construction of subjectivity. Simply put, phenomenology, which aims to go beyond the individualistic, solipsistic, and disinterested Cartesian subject, nonetheless remains Cartesian. Even though phenomenology corrects subjective issues, a separation between the subject and any type of historically given *matrix of intelligibility* still exists. All consciousness must go through a process; it emerges, develops, is critiqued, and then fades. This process is genealogy.

Genealogy responds to the problems of phenomenology by asserting that all knowing is a construct; instead of discovering the world, any given subject constructs the world in a certain way¹. Knowledge is not found, but made. An important dynamic arises out of this construction. On one hand, subjects correspond to worlds that can be known, yet, on the other hand, what can be known depends on what kinds of subjects can know. Thus, knowing within genealogy is simultaneously constructing worlds that can be known and subjects that can know. The question, then is, how embodiment may be constructed, and how this construction may affect the production of subjectivity.

A Genealogy of Modernizing Racism

A generative and pioneering genealogical account of racism is provided by Cornel West in his work *Prophesy Deliverance!*, which includes the chapter titled: “A Genealogy of Modern Racism”. In this chapter, West explains the conditions that are responsible for the conceptual, discursive, material, and material existence of white supremacy. West is interested in what Foucault would call the matrix of intelligibility of racist discourses, and their material efficacy. Still, West specifically examines modern, Euro-American discourses in his genealogy, and combines analysis of historical conditions, along with other pivotal discourses, namely those of philosophy and science.

Modern discourses on Race, for West, are shaped by three determinate historical factors: the scientific revolution, the Cartesian impact on philosophy, and the revival of classical aesthetic standards. First, the scientific revolution shaped modern discourse because it “...justified new modes of knowledge and new conceptions of truth and reality...” (West, 50), the scientific revolution, named as such, was truly a significant discursive revolution. Specifically, the scientific revolution brought about the principles of observation and evidence as central paradigms of Western knowledge. The scientific revolution did not “invent” these ideas, but rather “...brought these ideas together in such a way that they have become the two foci around which much of modern discourse evolves” (51). Instead of the scientific revolution being an isolated historical event, it gave birth to a new matrix of intelligibility, that of observation and

¹ Genealogy has two well-known and acknowledged key points of reference: Nietzsche and Foucault. Genealogy examines the interaction between life and history, which ultimately serves as a detector of moments or events that are biologically indexed. Nietzsche, in his “Advantages and Disadvantages of History for Life,” arrives at the possibility/impossibility, the benefits/disadvantages, and the chains/liberation that all of historical knowledge entails. On the one hand, the “correct” use of history, a knowledge of past strengths and the capacity to connect them with potential success, ultimately serves life and secures a successful future. On the other hand, too much can weigh on the shoulders of humanity like Sisyphus’ stone. History should not only be understood, chronicled and archived; it must also be used to exult life, to liberate us from the burdens of the past. The uses and applications of history are extended into his “Genealogy of Morality”. In this text, Nietzsche takes a look back to history, but now in terms of a temporal imprint on the flesh, in order to understand the concept of “good” and “bad”. However, these terms are not purely historical, and largely depend on their genealogical construction; the emergence of terms, the transformation from ‘term’ to ‘construct’, and the metamorphosis in which these constructs take on. Michel Foucault correctly observes that “The Role of genealogy is to record its history: the history of morals, ideals, and metaphysical concepts...as they stand for the emergence of different interpretations, they must be made to appear as events on the stage of the historical process” (Foucault, 86). Genealogy is not the mere hermeneutic or even existential understanding of concepts such as ‘good’ and ‘evil’, but rather the capacity to question the totality of such concepts.

evidence, which has shaped and continues to shape modern Western racial and racializing discourses.

Francis Bacon and Rene Descartes's works were determining for the emergence of this newly innovative and scientific matrix of intelligibility. Although widely considered key philosophical figures, both were significant proponents of the scientific revolution. West finds Bacon's importance in the fact that he believed "...the aim of philosophy was to give humankind mastery over nature by means of scientific discoveries and innovations" (51). The security of the human race's own supremacy over nature was perpetuated by science and guided by philosophy. Instead of coexisting with "other" organisms in a shared habitat, the scientific practice of observation and evidence elevated humans over "other" organisms and gave them authority over the habitat.

Going beyond Bacon, Descartes not only was a proponent of the scientific revolution, but also provided controlling themes of western discourse, "...the primacy of the subject and the preeminence of representation" (51). Just as Bacon established the priority of mankind, Descartes followed suit, and granted importance to the manifestations of the subject in addition. The effect the scientific revolution had on his work is clear, for "...he associated the scientific aim of predicting and explaining the world with the philosophical aim of picturing and representing the world" (51). He combines scientific orientation with philosophical motivation in order to establish a more rational reality that is to be both managed through science and mirrored in philosophy. It is important to remember the subject formed by Descartes philosophy, one that grants its own existence, one that is the source for its own knowledge, and enacts a radical doubt to the point where the body of the subject is disavowed.

At this point, a clear practice of observation and gathering evidence is coupled with scientific philosophy and an individualistic subject. The addition of an observational standard will motivate this subject to turn this practice into a method. This observational standard is what West calls the "...normative gaze'..." (53), a method that orders, compares, and categorizes the observations gathered by subjects. Most importantly, this "gaze" finds its root in classical aesthetic qualities and cultural norms. Superficial appearances, such as skin color, body shape, and facial structures as well as personal characteristics, such as temperament, sharpness, and amity were explored by this "gaze", which ultimately valued and continues to value one type of body – the white body. To put it clearly:

"What is distinctive about the role of classical aesthetic and cultural norms at the advent of modernity is that they provided an acceptable authority for the idea of white supremacy, an acceptable authority that was closely linked with the majority authority on truth and knowledge in the modern world, namely, the institution of science" (54).

It is the convergence of these emerging norms, namely the tools of the scientific revolution, the fusion of science and philosophy in order to establish supremacy of humankind, and, finally the standard quality of whiteness as a principle of supremacy, which combined to permit, authorize, and instigate discursive racism. West makes use of various anthropological and scientific studies within the modern period, all of which lead to the fallacy of black bodies that assume how superficial traits –the surface of the flesh— must presuppose a flawed, less-than-“human” character. At the same time, these “findings” served as a justification for the superiority of white bodies, which points to an interesting dynamic.

If Simone De Beauvoir addressed women as the “second” sex, investigations such as those carried out by West, taught us to see how black bodies (as well as other ethnic bodies) were also to be seen as “second” to the paradigmatic “white body.” If woman is second to male, black is

second to white. Still, it is unclear how the “second” compares to the assumed “first”. Yet, this ambiguity is the weightiness and persistence of race. Clearly, the “second” is the “other” of the “first”, but in what way? On one hand, the “second” could be viewed as an existential afterthought of the first, but on the other hand, the “second” may be needed to complete the first. It is clear that the latter is more relevant in both cases of race and gender. The “second” is essential to the extension of dominance, which the “first” has over the “second”. This means, the “second” must not only exist, but exist in a lesser way than the “first” in order of the “first” to exist at the standard it is accustomed to – supremacy. This genealogical relationship between “first” and “second”, the matrix, which they share, yet the subjective difference which divides them, is at the root of racism. Racism exists – but how does it manifest to and have an effect on certain subjects?

Towards a Political Phenomenology

To answer this question in part, Ta-Nehisi Coates gives his experience with the distinctive take on the effect of racism on “black” bodies in his work *Between the World and Me*. While this work reads as a personal narrative, it can and should be read as a political phenomenology or a radical genealogy of modern, or rather, contemporary, as in the latest version, of racism in the United States. Coates pays tribute to James Baldwin’s *My Dungeon Shook — Letter to my Nephew on the One Hundredth Anniversary of Emancipation*, and frames *Between The World and Me* as a letter to his son, which includes both the specifics of his own experience with interrupted subjectivity as well as instructions for managing his situation. This personal narrative is laden with examples that could construct it as a political phenomenology since Coates emphasizes the exploration of the black body and its situation. However, the work can also be seen as a radical genealogy, precisely because Coates critiques the Cartesian Subject through the allegory of what he calls the “Dreamers” and those bodies who ensure the dream of the “Dreamers”.

Phenomenological ideas become apparent in *Between the World and Me*, as Coates highlights the strife of the black body in a space where it is manipulated, degraded, violated, assumed always expandable, and sacrificial. However, it seems that he has taken on a Husserlian defense mechanism – synthesizing the way in which his country is failing him. As he gives advice to his son, he claims: “The greatest reward of this constant interrogation, of confrontation with the brutality of my country, is that it has freed me from ghosts and girded me against the sheer terror of disembodiment” (Coates, 12). As an interrupted subject, the synthesis within his own Cogito is not enough; Coates is weighed down with the responsibility of synthesizing the atrocities of his own country in order to remain autonomous with his embodiment. In neglecting to grapple with the violence laden within his culture and enacted upon his body as well as other bodies is to reject his own subjectivity. The black body, then, must work double-time in managing the relationship between its subjectivity and its situation in order to ensure the security of its embodiment.

Although this subjectivity may be interrupted, it is not entirely disjointed. Just as Maurice-Merleau Ponty postulates that our body is our vehicle to worldly experience, Coates posits, “...our bodies are ourselves, that my soul is the voltage conducted through neurons and nerves, and that my spirit is my flesh” (79). All bodies internally united in this sense, they are not a soul rattling within a network of bones, but rather a network of subjective attitudes and relationalities. The body is a memory, an emotion, an intelligence, a preoccupation, and a becoming. Spirit and

flesh are not affected separately, but rather work as one mechanism that both reaches out and is drawn into the world.

This body may be one, yet it is also endangered. Phenomenologically, the black body is complete in its existence, but it is subject to disembodiment. Although an interrogation into the black body as contrasted against its situation of precariousness may prevent disembodiment to a degree for Coates, he is able to capture the anxiety of being a black body. When speaking to his son about the anxiety of the black parent, he recalls his own father telling him “either I can beat him or the police” (82). Coates did not understand this principle until the birth of his son; it was then he understood the importance of the security of the black body. He explains the phrase, “That is a philosophy of the disembodied, of a people who control nothing, who can protect nothing, who are made to fear not just the criminals among them, but the police who lord over them with all the moral authority of the protection racket” (82). Fear is the controlling factor in the disembodiment of the black body. It constructs not only fear for the police, an “official” authority, but these fearful subjects will become subjects to be feared, and act out in their own violence. This point of fear and disembodiment lends itself to genealogy, as fear instilled into black bodies becomes fear of black bodies.

This construct of fear is only one genealogical example used by Coates. More vividly, he carries on the mission of West by also critiquing the Cartesian Subject, which can be directly related to what he calls the “Dreamers”. If individualism, solipsism, and radical doubt ground the Cartesian Subject within its situation, then the “Dream” protects and sustains the “Dreamer”. What is this “Dream”? Coates explains:

“I have seen that dream all my life. It is perfect houses with nice lawns. It is Memorial Day cookouts, block associations, and driveways...And for so long I have wanted to escape into the Dream, to fold my country over my head like a blanket. But this has never been an option because the Dream rests on our backs; the bedding made from our bodies...the Dream persists by warring with the known world.” (11)

Paradigmatically, the Dream works in two ways. On one hand, it is nostalgic; it evokes a certain warmth and promise for prosperity. It draws subjects in, and intoxicates them with an image of American success, pleasing homes and landscaping, the celebration of nationalistic holidays, and being submerged in a sea of sensibility. However, not all subjects are “Dreamers” and entitled to this privileged paradise; some are condemned to be the “damned”. These images, along with the feelings of warmth and nostalgia, are all predicated on the historical and contemporary violence inflicted on the black body. The Dream can only exist with a support, a subordinate existence, and its very own “second”. Again, we see the tension between “first” and “second”, and it is becoming more apparent that the suppression of the “second” is quite essential for the comfort of the “first”.

Coates is able to vividly illustrate his experience by placing the fearful embodiment of the black body within the matrix of the Dream. Clearly, Coates is not subjectively entitled to the Dream, but images of the missing Dream were laden within his situation just as much as fear was. He recalls, “Fear ruled everything around me, and I know, as all black people do, that this fear was connected to the Dream out there, to the unworried boys, to pie and pot roast, to the white fences and green lawns nightly beamed into our television sets” (29). This embodiment, which is colonized by fear, is now being drawn into the “Dream”, to which the benefits are flaunted, yet not granted to the black body. This double-offence inflicted against the black body works to oppress in two ways; while the black body is ruled by fear, it is also being exposed to

the freedom from that fear. It is not enough to be stigmatized; one must know that they are being stigmatized, which leads to further subject interruption.

Now, the black body is governed by fear, damned to be “second” to the “Dreamers”, and soberly aware to both factors of their situation. How is one to proceed? One may assume, as Coates briefly does, that the charade be exposed, and the “Dreamers” awake from their slumber and shake them out of their own constructs of whiteness. He gives candid instructions to his son, “...You cannot arrange your life around them and the small chance of the Dreamers coming into consciousness. Our moment is too brief. Our bodies are too precious. And you are here now, and you must live – and there is so much out there to live for...” (146-7). Instead of being concerned with the comprehension that the “Dreamers” lack, Coates suggests that his son focus on his own subject, live for the here and now, and find purpose in it. To attempt to wake the “Dreamers” is to continue the devastation of the black body.

The Gaze of Those Who Can Look

Both West and Coates speak on the concept of race broadly within both discourse and culture; their specific accounts of racism become apparent through either scientific studies (West), or personal experience (Coates). In order to ground the way race operates in a more universal experience, George Yancy explains what he calls “The Elevator Effect” in his work *Black Bodies, White Gazes*. The “Elevator Effect” is another genealogical tension between the black body and its interlocutor, the white body. Within this tension as well as the white gaze, the black body is phenomenologically limited, existentially controversial, and genealogically enlightened.

Specifically, this “Elevator Effect” speaks to the common situation of two people sharing an elevator. For some, this experience may be mundane, but when Yancy’s black body and a white woman share this space, something different happens. For Yancy, this space becomes transformed into different subjective paradigms, as the gaze of the white woman makes assumptions about his black body. In turn, he habitually synthesizes her behavior and comportment, and ponders the conditions for this construct.

A reemergence of the Cartesian Subject can be observed in the gaze of the white woman. She knows nothing about the person whom she shares the elevator with, but can observe his black body and construct her own image of him. She is the only individual in this space, which is being robbed from her by this “other”. Specifically, “She does not see a dynamic subjectivity, but a sort, something eviscerated of individuality, flattened, and rendered vacuous of genuine human feelings” (4). Through the gaze, she establishes herself as the only true ‘subject’ of the situation, and since she is the only subject, she has no responsibility to reach out to Yancy. Internally, she already holds all the necessary knowledge to judge this black body, which is predetermined by her gaze.

The solipsistic predetermination the gaze holds over the black body interrupts its intentionality. Recall Merleau-Ponty and his analogy between intentionality and a work of art. The artist communicates her message with the world through her art; subjects communicate their message with the world through their actions, which are brought to life by intentionality. The black body is denied this agency, as Yancy recalls as he stands in the elevator, “...it is as if I am no longer in charge of what I mean/intend...” (13). He is no longer able to organically express his intentionality through his actions, as any action will be interpreted by her gaze rather than his

original intention. The black body's ability to make actions legible to others is hindered by the concept of race, which judges actions before they come to fruition.

The combination of the Cartesian subject using white gaze and the freezing of intentionality also constructs the black body to hold a degree of its own solipsism. Since both the intentionality and the actions of the black body are presupposed by the white gaze, the black body is the only authority in truly knowing its own intentionality. To be clear, Yancy elaborates, "...it is if I am forced within an epistemic solipsistic position because her racist interpretive metanarrative chips away at my intended meanings." (16). He is forced into becoming an individual, who gains knowledge through solipsism, and is disinterested in the white woman's gaze. In this way, the black body ultimately is forced into being a Cartesian Subject by their intentions becoming silenced.

How is this submission able to proceed? By assuming the nature of the black body. Mirroring Beauvoir, Yancy uses existentialism as an account for his body, which is considered "other" and made submissive within the white gaze. However, instead of being entitled to the freedom of forming their own subjectivity and instead, constructing it for the other as the subject-as-woman does, the black body is existentially exempt from freedom. Yancy affirms, "From the perspective of whiteness, I am, contrary to the existentialist credo, an essence ("Blackness") that precedes my existence" (Yancy, 1). Existentialism maintains that existence precedes essence, and the subjects find their freedom through this rule. Black bodies, however, are exempt from this, and have an assumed essence based on the status of their appearance.

The racialized subject carries an essence of "blackness", which determines the way this subject manifests to others. However, what kind of manifestation takes place? How is the black body taken up? To answer, Yancy suggests "...one might say that Blackness functions metaphorically as original sin. There is not anything as such that a Black body needs to do in order to be found blame worthy" (5). Now, this predetermined black body is essentially guilty, a subject-to-be-blamed. Inherently, this body is worthy of blind distrust; instead of being a subject in fear, as Coates asserted, the black body is a feared body.

The white gaze shapes this clear image of the black body as something to be apprehensive of, just as the male gaze shapes a clear image of the female body as something to behold. Just as the male gaze distorts the line between culture and nature on the feminine body, the black male body is also naturally distorted. As Yancy and his fellow passenger share the elevator, she attempts to "protect" herself from his black body by the clutching of her purse and closing of her stance. Yancy's sexual status as a black man is evoked in this movement, specifically the "...reality of our dual hypersexualization: 'you are either a sexual trophy or a certain rapist.'" (16). The male gaze sends contradictory messages in standardizing the woman; the white gaze constructs the disjointed nature of the black male body. This body is to be feared, yet to be desired; the black male body is both a horror and a conquest.

What shapes this white gaze? One could reconsider the construct of having a "first" and "second", but that explanation is too direct. Yancy makes a significant judgement on the white gaze of the woman with whom he shares the elevator, explaining:

"Her "reading" of my Black body is characteristic of the epistemology of ignorance. More specifically, an epistemology of ignorance involves 'a particular pattern of localized and global cognitive dysfunctions', producing the ironic outcome that whites will in general be unable to understand the world they themselves have made. She suffers from a structured blindness, a sociopsychologically reinforcing opacity that obstructs the process of 'seeing'

beyond falsehoods and various modes of whitely body comportment that continue to reinforce and sustain white hegemony and mythos” (22)

To say that this gaze is constructed consciously is giving too much credit to the holder of the gaze; clearly, this gaze is the product of a paradigmatic construction. Such a construction is clearly misleading, and not grounded in any certain truth. Thus, the condemnation of the black body is not an essential fault, but rather a construct of the white gaze. This gaze does not shape black bodies, it determines them; the inner subject of the black body is marked by the indelibility of its own appearance. Furthermore, this white gaze feeds white dominance; it operates on a subconscious level, making those who look with the gaze blind to its consequent damage.

Besides the shaping of the black body, what other power does the white gaze hold? Simply put, it can reconstruct spaces, making an otherwise impartial situation into a genealogical hotbed. In the “Elevator Effect” Yancy takes note on how the elevator transforms in the presence of the white woman’s gaze, “The apparent racial neutrality of the space within the elevator has become an axiological plenum, one filled with white normativity” (15). Suddenly, this neutral space for Yancy has become something he is feared in and unwelcomed to. He is receptive to this shift, and ultimately aware of the paradigm that controls and defines his own body. This conditions him, as well as other black bodies, into being genealogical knowers.

The transformation made in the elevator is not singular in effecting Yancy, but also defines and limits the white woman in a certain way. Clearly, she limits the expression of the black body standing before her, but as she rigidly defines this body, she also adheres herself to a certain standard, “...it is important to note that not only does the white woman in the elevator ontologically freeze my “dark” embodied identity, but she also becomes ontologically frozen in her own embodied (white) identity” (19). Her ontological status as a white body apprehends her to her own ignorance. She is not aware of her white gaze, and how it not only constructs the black body standing before her, but also herself. She is ultimately limited in her own subjectivity as she limits the subjectivity of her other.

The white gaze is limited in its scope, and fails to see the way it limits its own white body. However, the black body, being cast into this matrix of white regularity, gains a certain responsiveness at the inception of this matrix, which becomes clear as the white body reacts to the presence of a black body. Explicitly, “...Blacks do in fact possess a level of heightened sensitivity to recognizable and repeated occurrences that might very well slip beneath the radar of others, who do not have such a place and history in a white dominant and hegemonic society” (6). The black body is existentially shaped by the white gaze, but this gaze is blind. White bodies, especially male white bodies, are entitled to being standard subjects in society. They do not evoke the raising of the eyebrow, or the clutching of a pocketbook, or the façade of a genuine smile. Black bodies, however, are conditioned by these habits while in this matrix of white normativity, in which they become keen in assessing their situation.

Conclusion: Race as a Matrix of Unintelligibility

After these considerations, then, how does this world of constructed subjects within their respective matrixes of intelligibility affect subjects that are exposed to racism, in fact, that are constituted as racialized subjects? To be more specific, this happens in a number of ways. First, it seems that the embodiment of black bodies begins the disruption of their subjectivity. This embodiment is not mitigated by the subject itself, but rather robbed from the subject. This disembodiment of the black body is a clear response to a fear instilled into their subject given the

violence inflicted upon them in order to sustain the comfort of the American Dream. Merleau-Ponty's embodied subject, who is entitled to be in the world purely, is no longer applicable – black bodies are not free bodies.

More significantly, the black body is exposed to a number of matrixes, all which include the submission of their subject. This requires a Husserlian defense mechanism, wherein the racialized subject not only synthesizes its own being, but also must interpret both racist macroaggressions and general systematic racism and contrast the two. Their cogito is being extended to include a paradigmatic tradition of racism, which ultimately reaches to them and affects their subjectivity.

The underlying interplay between “second” and “first” as seen in Beauvoir's *The Second Sex* can be applied to racialized subjects. West is able to clearly articulate how black bodies became deviant to the standard white body, but is the construct *true*? A great deal of ambiguity exists between the “first” and the “second”; Yancy is able to clearly display this in constructing black bodies as genealogical knowers. Thus, the “second” is not essentially subordinate to the “first”, but rather constructed and suppressed into their situation.

In the contemporary world, subjects become objects of race through the persistence of the Cartesian Subject, which becomes revived as a disinterested scientist in the work of West, an individualistic Dreamer in Coates' account, and manifests as a solipsistic gaze for Yancy. All three accounts provide certain realms in which racism becomes enacted through discourse, personal experiences, and mundane accounts. The recognition of this passive apathy by the modern ghosts of the Cartesian Subject would be a pivotal step towards progress, but whether or not we are to occupy ourselves in the freeing of consciousness for those who wish to remain sedated is unclear. Coates will disavow this effort, and suggest subjective autotomy, but I think these connections are too strong to be taken for granted. The concept of race is grounded in history, develops through genealogy, and made manifest in phenomenology – and that is worth examining.

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***Imitation of Greatness:
Alexander of Macedon and His Influence on Leading Romans***

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Abstract

This paper seeks to examine the relationship between greatness and imitation in antiquity. To do so, Alexander the Great will be compared with Romans Julius Caesar and Marcus Aurelius. The question this paper tries to answer concerns leading Romans and the idea of imitating Alexander the Great and how this affected their actions. It draws upon both ancient sources and modern scholarship. It differs from both ancient and modern attempts at comparison in distinct ways, however. This paper contains elements of the following: historiography, biography, military history, political science, character study, religion and socio-cultural traditions. Special attention has been given to the socio-cultural differences of the Greco-Roman world. Comparing multiple eras allows for the establishment of credible commonalities. These commonalities can then be applied to different eras up to and including the modern. Practically, these traits allow us to link these men of antiquity, both explicitly and implicitly.

Beginning with Plutarch in the 1st/2nd century CE¹, a long historical tradition of comparing great men was established. Plutarch chose to compare Alexander the Great to Julius Caesar. The reasons for such a comparison are quite obvious. Both men conquered swaths of land, changed the balance of power in the Mediterranean and caused many to either love them or plot to kill them. Scholars have assessed this comparison continuously. This paper contributes to a specific niche within that vein of scholarship by reexamining leadership styles to reveal traits, which both made Alexander great and a subject of Roman imitation.

Ancient sources and modern scholarship have discussed this comparison at length. The framework of this paper differs from previous scholarship in notable ways. The content will be framed based on the military political and personal exploits of each man. Leadership traits such as self-belief, ambition and ability to inspire subordinates will frame the discussion. For the purpose of this paper, Alexander will be compared with Julius Caesar and Marcus Aurelius. In addition, it provides new considerations about greatness. Foremost among these considerations is the idea that there is more than a single way to be a great leader in antiquity. Marcus serves as an example of a leader whose greatness did not come because of military conquest. In actuality, Marcus' avoidance of Alexander's character flaws proved crucial to his own greatness.

¹ Plutarch lived from 46 CE – 120 CE.

Alexander the Great: Self-belief and Ambition

Alexander the Great, or Alexander of Macedon, lived from 356-323 BCE. He was born the son of Philip II, King of Macedon, and Olympias. He enjoyed all the luxuries of the Macedonian imperial court. Aristotle personally tutored him and Alexander had a good relationship with his tutor.² Alexander later praised Aristotle for allowing him to live a “noble life”. During Alexander’s adolescent years, a number of anecdotes are handed down regarding Alexander’s sense of destiny to be greater than those before him. The most noteworthy is Alexander’s taming of the horse Bucephalas. Philoneicus the Thessalian brought the horse to the court of Philip offering to sell him. Philip and many of his subordinates tried to ride the horse but the horse refused to be ridden. Alexander declared boldly that he could do that which the others failed to do. Supremely confident that he understood the problem, Alexander offered to pay the sum for the horse if he was unsuccessful. Alexander successfully rode the horse after he turned the animal away from his shadow. Alexander’s father wept for joy and told Alexander that Macedonia was far too small for him.³ This circumstance relates to Alexander’s self-belief in two ways. First, Alexander showed a great amount of confidence when he approached the situation. He was certain that he could succeed where others had previously failed. In this situation, Alexander’s audacious decisions are marked by either foolishness or hubris. Alexander risked embarrassing both his father and himself in the eyes of respected men. This provides a sense of Alexander’s level of self-confidence. Second, an overjoyed Philip stokes Alexander’s already burning ego. With his reaction and words, Philip not only approved of Alexander’s ego but also fostered it. While this anecdote likely was fabricated, it still demonstrates that in the eyes of that society Alexander was set apart to be great.

Another instance of Alexander’s self-belief concerns the story of the Gordian knot. While on campaign in Asia Minor, Alexander came to the site of the knot. According to legend, whoever loosened the knot was destined to rule the world. Alexander bent on conquest of Asia takes it upon himself to loosen the knot. After surveying the situation, Alexander determined that he could not simply untie the knot. Being Alexander and possessing a high degree of confidence, he unsheathed his sword and cut the knot. This proved that Alexander was destined for greatness in the eyes of the gods.⁴ Alexander made a clear statement about his intentions to rule all of Asia. Spiting all of those before him, he declared himself the rightful fulfiller of the prophecy.

The siege of Tyre exemplifies the negative consequences of Alexander’s ambition. Alexander undertook a siege of a fortified island without a fleet. Persian dominance of the Mediterranean made taking the island fortress more difficult. The prolonged siege speaks to his ambition, which resulted from Alexander’s self-confidence. Alexander’s ambition got the better of him at Tyre. He spent seven months besieging the coastal city, needing ships from Phoenicians to properly attack. The Macedonians attempted to build a causeway to the island from the land. Considering all that Alexander

² Plutarch, *Life of Alexander*, VII.2-5. Plutarch contrasts the positive relationship between Aristotle and Alexander with uneven relationship he had with his father Philip.

³ Plutarch, *Life of Alexander*, I.6.1-8.

⁴ Quintus Curtius, *Life of Alexander*, III.11-18.

conquered in ten years, the time spent at Tyre seems disproportionate. Multiple times Alexander took actions simply to gain the reputation for doing things, which others could not.⁵

Possessing all of Asia may not have even satiated the ego of Alexander. His self-belief reached divine heights. While in Egypt during February 332, Alexander sought out an oracle to Jupiter Ammon to find out if he was truly the son of a god—not Philip but Ammon (Or Zeus to the Greek or Macedonian mind). Alexander believing himself divine searched out proof. Some sources tell us that Alexander’s own men were convinced of his divinity. The priests serving at the oracle decreed that Alexander was the son of a god. Regardless of Alexander’s mental state previously, Arrian tells us that he left with the mindset that he was linked to Ammon.⁶ Alexander’s self-belief, whether considered appropriate or megalomaniacal, set the foundation for the actions that Alexander undertook.

One of the reasons for Alexander’s military greatness was the technological advantage that he brought into battle. The Persians relied on the dated technology of Greek mercenaries⁷ to make up their infantry. The Greek phalanx was developed centuries before Alexander. The phalanx consisted of heavily armored hoplites fighting in close quarters, hand-to-hand combat. Philip II, father of Alexander, developed the Macedonian phalanx in response. These soldiers were equipped with a spear called a sarisa, which was 13-20 feet in length. This gave the Macedonians a distinct reach advantage, if well trained. These developments mitigated the two great strengths: the armor worn by hoplites and their hand-to-hand prowess. The length of the sarisa gave great force and leverage to counteract the armor and negated the reach of the Greek phalanx. The Persians also relied on a haphazard conglomeration of multi-ethnic peoples to fill out their ranks. Alexander further expanded upon his advantage with the companion cavalry, so named for their close relations with the king. These elite units trained together for years, developed a sense of cohesiveness, and were occasionally equipped with sarisas. Their training and ability played crucial roles in the battles at Issus and Gaugamela.

Alexander in Battle: Granicus and Gaugamela

Alexander the Great is most famous for being a conqueror who never lost a battle. One of the most important traits that drove Alexander’s greatness was boundless ambition. Believing he was meant for greatness, Alexander became ambitious where others were restrained. A proper example of his ambition can be seen in his insistence to fight at the Granicus River. Alexander had just crossed the Hellespont and this battle proved to be his first major conflict in the conquest of Asia.⁸ Alexander’s army spread

⁵ Curtius mentions Alexander’s siege of the rock fortress at Aornos. Taking place later in Alexander’s campaign, the fortress was located in a far off reaches of Asia. Alexander showed that he believed that he could go to the ends of the earth, conquering any task set before him.

⁶ Arrian, *The Landmark Arrian: The Campaigns of Alexander (Anabasis Alexandrou)*, III. 3-4.

⁷ These Greek mercenaries hired themselves out on both sides of the conflict.

⁸ Spring 334 BCE.

out on the western bank of the river, while western Persian satraps aligned their troops on the other bank. Alexander's troops were laid out with cavalry on the wings and the phalanx in the middle. Alexander commanded those on the right while his trusted general Parmenio⁹ commanded those on the left. The Persians aligned their cavalry in front of the hired mercenaries from Greece. Alexander started the conflict by sending his cavalry from the right flank across the Granicus, forcing the Persians to engage with the Macedonians on that wing. There was a struggle to find footing and then infantry followed. Intense fighting followed in close quarters.¹⁰

Alexander's initial sortie made a wedge in the Persian cavalry lines. Alexander chose to personally exploit this hole, leading two detachments of cavalry into the fray. Alexander showed himself to be brave, as he got cut off from his troops and nearly was cut down. However, the ruse worked and the Persian cavalry fled. At the same time, Parmenio put the other wing to flight. The Macedonians were able to surround and decimate the Persian infantry.¹¹ Alexander's blend of tactics, ambition and bravery helped the Macedonians to win the day. Typical battlefield strategy would dictate that Alexander not be the one cross the river and that he fight the Persians in a more confined area where their numbers would be less advantageous. Ignoring these conventions, Alexander demonstrated his ability to achieve a victory despite the circumstances. A confluence of Alexander's leadership traits made the Macedonians successful at the Granicus.

The Battle of Gaugamela further demonstrates Alexander's ambition and its role in his greatness. Alexander had successfully defeated Darius at Issus two years previously and then subdued the rest of Phoenicia and Egypt. After that time, Alexander finally was able to get close enough to Darius to fight a decisive conflict. The site of Gaugamela is an open plain in modern day Iraq. Alexander has 47,000 troops and Arrian states that Darius had as many as 1,000,000 men.¹² Curtius gives us a speech that was supposed to be given by Alexander before the battle. In his speaking, he displays another important leadership trait: the ability to inspire men. He makes two very powerful appeals. Alexander claims that the battle will determine who is sovereign in Asia. Clearly, this situation carries quite a lot of gravitas. In addition, Alexander states that his men were born to fight nobly so they need not be heroes; instead, they simply need to perform their duty.¹³ Alexander inspires his men both by stating his belief in their natural ability and by clarifying their responsibility. It remains incredible that Alexander inspired his men to victory given the numbers. Despite ancient sources often inflating numbers, Alexander was still most likely outmanned at least two-to-one. It is important to remember the psychological effect in warfare. Alexander stands before the men he addresses undefeated, having loosened the knot at Gordion, claiming divinity. Truly, Alexander's self-belief laid the foundation for him to be ambitious and inspire his men. The speeches delivered by Alexander were not remarkably different from other

⁹ Parmenio commanded troops under Alexander's father Philip also. He was one of Alexander's most trusted advisors.

¹⁰ Arrian, *Anabasis Alexandrou*, I.12.6-17.2.

¹¹ see 11.

¹² Arrian, *Anabasis Alexandrou*, III.11.4-6.

¹³ Arrian, *Anabasis Alexandrou*, III.11-12

The Persians were arrayed in the following way facing Alexander: Mazaios commanded the cavalry on the right, Darius the center including the scythe chariots meant to cut down the Macedonians. Bessos lead the cavalry opposite Alexander's right. Alexander controlled the right flank and Parmenio the left. Philotas, the son of Parmenio, commanded the companion cavalry. Alexander first moved the right wing to rougher ground, which made it more difficult for Bessos' men. Bessos attempted to take the wing from Alexander, but the Macedonians prevailed. Darius then released the scythe chariots. The effect of these chariots on Alexander's line was negligible. Mazaios launched his cavalry against Parmenio trying to outflank him. As the battle raged on the left flank, Philotas and Alexander broke through the Persian center, causing Darius to flee. Once their commander fled the center and left folded for the Persians. The Persian success against Parmenio opened a gap that the remaining Persians exploited, making for the Macedonian baggage train. They looted until the rear phalanx maneuvered to stop them. However, Parmenio was surrounded and appealed for Alexander's help. Alexander called off his pursuit of Darius and peeled back to defeat Mazaios.¹⁴ The Macedonians defeated the Persians and Alexander proved his military greatness once again. He fought on a battlefield better suited to his opponent, commanded less men and dealt with the Persian push to his wagons. Gaugamela was a coming together of all the traits that made Alexander great – tactical prowess, ambition, inspiration and self-belief.

Alexander and Politics

Alexander is best known as a military conqueror, but to determine what truly made him great it is important to examine his political actions as well. Alexander was born as a prince so the resulting political environment is quite different from that of either Julius Caesar or Marcus Aurelius. Macedon was ruled by hereditary monarchy, meaning that Alexander was next in line to rule after his father's death. Caesar rose to power during the late Roman Republic and M. Aurelius was adopted into the imperial family¹⁵ before becoming emperor. The major difference between these systems is clear. In a monarchy, the ruler justifies rule through bloodline. For both Caesar and especially Marcus Aurelius, power came from merit.¹⁶ The central problem politically for Alexander concerned leadership problems that arose during his conquest of the Persian Empire. Alexander was not only ruling over the Macedonian political situation but also dealt with presenting a positive message to the peoples he conquered. At the heart of the issue, is this one central question: to the conquered was Alexander a rightful ruler or foreign conqueror? Alexander gave himself over to Persian customs. Curtius states that Persian dress and customs were of greater grandeur. Alexander tried to compete with the opulence of Darius' court in terms of dress, luxury and obeisance. Curtius states that the man who conquered Persian now conducted himself as a satrap of Darius.¹⁷ Alexander's wearing of Persian dress contains strong symbolism about the nature of his rule. Alexander presented his wearing Persian dress as a display of unity but Alexander

¹⁴ Arrian, *Anabasis Alexandrou*, III, 13-17.

Curtius, *Life of Alexander*, IV. 14.1-7.

¹⁵ None of the so-called Five Good Emperors was the son of the previous emperor.

¹⁶ Caesar rose to power on merit but usurped power of his own accord.

¹⁷ Curtius, *Life of Alexander*, VI.1-9.

preferred the grandeur of that garb. In view of all the things that Alexander did, the forced obeisance made subordinates, both Macedonians and Persians,¹⁸ the most furious. Alexander made all people in his presence submit in this manner. Persians who declared their loyalty to Alexander had functioned under this type of court but those native to Macedonia and Greece had not experienced this type of adoration for a ruler. Even worse, they viewed this act as an affront to Greek and Macedonian customs. The Persians laid prostrate before their native kings and Alexander commanded that this honor be given to him because he believed in his own divinity.

Alexander's Flaws: Loyalty and Drunkenness

As tensions continued to increase so did the attempts to assassinate Alexander. The crescendo of these attempts involved Parmenio and Philotas. Philotas commanded the companion cavalry and was well respected by Alexander. Philotas was given a proper trial before his countrymen and evidence was brought forth showing his involvement or at least his knowledge of a plot against Alexander. Philotas was executed and another respected general Amyntas was implicated and executed at the same time. Lastly, Parmenio, the most trusted among Alexander's advisors and most capable subordinate, was killed.¹⁹ Alexander believed that he had to be killed. Not only was his son Philotas executed, but also he was respected among all the troops and would be capable of causing division and rebellion among the ranks. Alexander's greatness militaristically was due in large part to these men, all of whom commanded troops at the Granicus and had been with him since. Alexander's great conquest made his political situation increasingly difficult. Alexander dealt with revolts from Greece under Lacedaemonian King Agis and frequent revolts from Persian satraps.²⁰ Because of the stresses of placating both Macedonians and conquered foes, Alexander's camp became rife with factions and made his campaigns more difficult.

These divisions spilled over into Alexander's personal life when he made decisions about who commanded troops and advised him. Consider Hephaestion. A friend of Alexander's from youth, he gained more responsibilities because Alexander knew that he could trust him. Alexander could be confident of this because Hephaestion owed his status entirely to Alexander. Hephaestion led troops in India because of Alexander's trust in him. This speaks to the importance of loyalty for Alexander during a time of greater personal peril. Hephaestion certainly was not as capable a commander as Philotas but he provided trustworthiness, which Alexander desperately needed. Alexander was willing to allow Persians the same roles that they enjoyed under Darius, if they had proved loyal.²¹ Great men understand the importance of surrounding themselves with those who are loyal over those who show more ability.

¹⁸ Persians did not detest this practice since Persian imperial court customs called for this type of sacrosanct treatment.

¹⁹ Arrian, *Anabasis Alexandrou*, III.1-4

Curtius, *Life of Alexander*, VI.9.7; VI.11.10-23.

²⁰ Agis and the Spartans rebelled in 330 BCE. The satrap Satibarzanes rebelled against Alexander twice.

²¹ Nabarzanes is a notable example.

Alexander's largest character flaw was his love of drink. This led Alexander to often act foolishly. He once was nearly killed because of comments made to his father at dinner. Two examples from his campaigns stand out. At Persepolis, he commanded the Persian palace complex be burned. Primary sources confirm this act was one of the most regrettable for Alexander. In addition, he killed Kleitos with a spear while drunk. Alexander and Kleitos had been arguing over whether Alexander or Philip's leadership was greater.²² Alexander later regretted burning the palace. Kleitos was a man who had become annoyed by Alexander but did not deserve to die. Alexander's excessive of drinking left destruction in his wake.

In Alexander, one sees many of the traits needed for greatness – self-belief, ambition, and inspiration of men. How did Romans try to imitate greatness and avoid the flaws of Alexander?

Julius Caesar: Influenced by Alexander from Adolescence

The name Julius Caesar conjures up many images. Caesar²³ can be seen as the conquering general, dictator given to debauchery, or as an arbiter of political power. Regardless of how he is viewed, Caesar is respected for his greatness. Similar to Alexander, Caesar exuded self-belief from a young age. As a young man, pirates kidnapped him. Caesar spent forty days with the pirates. When they told him of their intentions to sell him, Caesar told them that they should ask for more. Caesar then also told his captors that he would capture and crucify each one of them, which he did.²⁴ It takes a large amount of confidence to threaten the men who are in charge of your life – especially when your captors are pirates whose only interest is making money. Self-belief was required for Caesar to have the military and political career for which he became famous.

Caesar's Campaigns – Alesia & Pharsalus Examined

Caesar's first major successes on the battlefield took place in the Gallic frontier. Caesar reached the height of Roman political office in 59 BC when he was elected consul. After his term ended, he received the provinces of Cisalpine Gaul, Transalpine Gaul and Illyricum. These provinces supplied Caesar with the two things that he needed the most: the ability to prove himself militarily and gain a sufficient amount of wealth to pay off his creditors.²⁵ During his time in Gaul²⁶, Caesar showed that he was adept at leading an army and incorporated the rest of Gaul into the Roman state.

No conflict demonstrates Caesar's veritable military skill better than the Battle of Alesia, which proved to be decisive in Caesar's conquest of Gaul. Fought in September of 52 BC, the engagement effectively brought Gaul under Roman control. After a bloody battle fought days before, Caesar followed the Gallic army to the stronghold at Alesia. While in pursuit, the Romans cut down many of the enemies' rear guard. The Romans set up for a siege of the city, realizing that the people of the city as well as the army had

²² Arrian, *Anabasis Alexandrou*, III.18.11-12; IV.8-9.

²³ 100 -44 BCE.

²⁴ Suetonius, *divus Julius*, 4.

²⁵ Gaius Suetonius Tranquillius. *The Twelve Caesars*, *divus Julius*, 23.

²⁶ 58-51 BC.

enough provisions for only one month. With his opponent Vercingetorix inside the city, Caesar ordered the Romans to build a wall around the city. This entrenchment effectively would blockade the city. The German and Gallic combined forces held a distinct advantage in the number of cavalry among their ranks. As the Romans built the wall, the barbarians decided to send out horsemen under the cover of night to muster more troops. They asked for a certain quota from each of the peoples opposing Rome. Caesar ordered a second wall built to protect the Romans from the forces that would place Caesar between the city and the newly mustered troops. The number of mustered troops came to 250,000 infantry and 80,000 horsemen. In addition, the Romans built several obstacles besides the wall. The Romans constructed palisades five rows deep out of trees nearby, diverted one of the two rivers to fill a trench and placed spurred logs. These logs were placed at an angle, meant to tear up flesh and mangle armor. They dug pits, some filled with spikes and others eight feet deep. Twenty-three forts dotted the wall along with high earthen walls and siege towers. These fortifications stretched for a perimeter of 11 miles. Germans and Gauls attacked from within and without for three successive days, and more fiercely each day. After the engagement ended, as many as 90,000 Gallic soldiers laid dead. The Gauls did break through the walls at certain points, forcing the thin line of Romans to grow thinner still. Caesar himself (not unlike Alexander the Great) personally commanded troops against Gauls at specifically weak points when his subordinates failed.²⁷ Caesar displayed traits that indicate that he was an excellent tactician. Caesar followed up his previous victory with pressing the enemy harder. Using the entrenchments, Caesar denied the advantage of numbers to the Gauls. Caesar faced frequent revolts and rebellions by the Gauls during each campaign season. Not only did Caesar repulse these attempts but incorporated a new Roman province. This is a key difference between Alexander and Caesar. Alexander was battling a well-established civilization. Caesar was bringing Roman rule to a loose confederation of people in Gaul.

Caesar also outmaneuvered Pompey at the Battle of Pharsalus during the Civil Wars. Despite having a distinct disadvantage in numbers of horsemen, Caesar chose to fight this battle inland, where Pompey's naval ability to supply his army would be diminished. Acting on this perceived advantage, Pompey dispatched forces to exploit this advantage, but before the battle started, Caesar sent six cohorts to the weak flank covertly. As a result, Caesar was able to outflank Pompey and defeated him. Caesar made use of his calm demeanor during the din of battle. He was able to see the field of battle with clarity and make the best decisions. Moreover, he showed that he was able to learn from his loss at Dyrrhachium and adjust. Caesar displayed greatness in his ability to inspire men as well. After Dyrrhachium²⁸, Caesar undertook his own personal mission to recover supplies. The troops were so distraught that he would do so without them. Caesar thus inspired men who had been soundly beaten to beg for another chance to show them victorious. This also shows that Caesar was able to win against an enemy equipped with the same technology as himself. Alexander did not face that problem during his conquest, although Caesar's technological advantage in Gaul was similar to the Alexander's advantage against the Persians.

²⁷ Gaius Julius Caesar, *De Bello Gallico*. VII. 63-90.

²⁸ Julius Caesar (trans. Cynthia Damon), *Civil War*. Loeb Classical Library, 2016. III.88-99.

Caesar: Politics of Dictatorship

Caesar's political career took place against the background of the Late Roman Republic. Rome suffered from the Social War of Marius and Sulla.²⁹ There was a political schism between the Optimates and Populares. The Optimates served the interest of the political elite, while the Populares advanced the interests of the common people, or plebeians. Caesar, a member of the Populares, won his first election in 76 CE as tribune.³⁰ Caesar fought on behalf of the people and garnered a reputation as a defender of the Plebeians. As Caesar climbed the *cursus honorum*, he gained a popular backing. This popularity gave birth to his ambition. In 60 CE, Caesar wished to run for the consulship in the upcoming year. He sought out allies who could help him win the election. He made a three-way pact that has come to be called the first Triumvirate. He did so with two illustrious Romans, Pompey the Great and Marcus Crassus. Pompey won fame for his generalship in the east. Crassus was the richest man in Rome, capable of fielding his own personal army. Caesar won the consulship in 59 BCE and all of the men agreed to rule jointly, despite the other consul being Marcus Bibulus.³¹ Caesar ruthlessly fought Bibulus at every opportunity. Bibulus became so disgusted that he did not bother to show up publicly after the first few months. Caesar turned his consulship into a military command in Gaul. Afterwards, Caesar's ambition reached its zenith. In 49 BCE Caesar crossed the Rubicon, declaring civil war after the Senate refused to give into Caesar's demands,³² won the conflict and was declared dictator, first for ten years and then life. In fact, Caesar turned down very few honors.³³ Caesar's ambition knew no bounds. The only thing that stopped Caesar's ambition was death. Caesar made clear that he planned to undertake great tasks as dictator such as an urban building program and a campaign against the Parthians to the East. Ambition is the trait that most marks Caesar's political career.

Caesar: Personal Life and Link to Alexander

Caesar's personal life contains both positives and negatives. Caesar is noted by both friends and sources as refraining from drinking. Caesar did so to keep a sound mind. Caesar was plagued by rumors about his sexuality from his youth. He received a reputation for homosexuality while at the court of an eastern client king. He also was known to frequent brothels whilst on campaign. Caesar did however put his morality on display during one particular instance. Publius Clodius attempted to seduce his wife, Pompeia, at a festival for women only. He did so by dressing as a woman. Despite proof that nothing of a sexual nature happened Caesar decided to divorce Pompeia, stating, "The wife of Caesar must be above suspicion".³⁴ Both political enemies and his own

²⁹ 91-88 BCE.

³⁰ Tribunes of the plebs were given veto power over legislation and expected to protect the common people. This was the first step in the Roman *cursus honorum*. Romans climb through offices culminating with the consulship and entrance into the Senate for those not of Senatorial stock.

³¹ Suetonius, *divus Julius*, 19.

³² Plutarch, *Life of Caesar*, XXVIII,

³³ Plutarch, *Life of Caesar*, LVII.

³⁴ Plutarch, *Life of Caesar*, X.

legions note Caesar's sexuality. Alexander is known for his sexual abstinence. Caesar and Alexander clearly have different personal vices. Caesar takes great care to avoid excessive drink, Alexander's greatest flaw. In some ways, Caesar learned from the negative aspects of Alexander's character despite flaws in his own.

Caesar has undeniably been linked with Alexander. The strongest case for Caesar himself making a comparison with Alexander comes from his time spent as a quaestor in Spain. He found himself in a temple to Hercules in modern-day Cadiz. He was heard sighing audibly and talking about how Alexander conquered the world at his age and Caesar felt he had done nothing in comparison.³⁵ This shows that Alexander's accomplishments were in the mind of Caesar. In addition, he was known to have been reading the history of Alexander around the same time. Furthermore, he became involved in multiple plots to overthrow the state after his quaestorship ended. The timing of such actions show that Alexander Both Caesar's words and actions confirm his looking back to Alexander.

Marcus Aurelius & Different Type of Greatness

Marcus Aurelius Antoninus lived from 121 – 180 CE and reigned as the last of the so-called Five Good Emperors. He grew up under Emperor Hadrian (r. 117-138). Emperor Antoninus Pius (r. 138-161) adopted a young Marcus into the imperial family.³⁶ The Roman imperial environment forced Marcus to adapt to a certain way of dressing and acting. As for Alexander of Macedon, all the resources necessary were brought to bear to groom him for leadership. Alexander became vainglorious and overly ambitious as a result. Alexander had to deal with a legacy of military success. Philip incorporated all Greek lands excluding that of the Lacedaemonians. Life in the imperial court seemed to have the opposite effect on Marcus. After conquering the Persian Empire, Alexander gave himself over to debauched living. He drank excessively and dressed in Persian royal garb.³⁷ Marcus paid attention to his studies, often until it was unhealthy.³⁸ Marcus was ambitious, indeed. His ambition was not self-glory but wisdom. In fact, Stoic philosophy, which he studied intently, formed the foundation of how he thought and governed. This basic difference between these two rulers underscores a deeper point regarding Marcus Aurelius. Alexander the Great and Julius Caesar fit into the same mold of leadership. Both were conquering generals, which society tends to view as the most common form of masculine heroism. Marcus garnered an equivalent amount of respect but does not fit the same mold as Alexander or Caesar.

Marcus Aurelius' legacy does not evoke thoughts of supreme military generalship. This does not mean that the Roman military did not operate effectively during his reign. Marcus' legates acted swiftly to put down revolts in Spain and Egypt. Avidius Cassius, who received the power of *imperium* in the eastern Roman provinces,

³⁵ Plutarch, *Life of Caesar*, XI.

³⁶ Translated by David Magie. *Historia Augusta Vol I: Life of Marcus Aurelius*, Loeb Classical Library, Harvard University Press (Cambridge, Mass), 1921. 4.1.

³⁷ Arrian (Ed. James Romm). *The Landmark Arrian: Campaigns of Alexander*, bk. VII. 6-8.

³⁸ *Historia Augusta: Life of Marcus Aurelius*, 3.6

put down the rebellion in Egypt.³⁹ In 175, Cassius led a rebellion himself, thinking that Marcus had died and not wanting the young Commodus to rise to power.⁴⁰ This once again calls to mind the question of loyalty. Marcus' trust of Cassius is one of the few, clear political stains on his reign. Marcus waged war successfully in Parthia and Armenia until Cassius' rebellion. Caesar never was able to undertake a campaign against in the east. For these exploits, Marcus received honorary titles from the Senate. Marcus also led a successful war against the Marcomanni and other German tribes. This campaign stopped raids across the Danube into Roman territory. The campaign started in 166 CE and continued through Marcus' death in 180. Ancient sources posit that one more year may have been enough to incorporate Marcomannia and Sarmatia as provinces.⁴¹ Despite not being a conqueror, Marcus did many positive things. Marcus was noted as a man who "made bad men good and good men great."⁴² The author of the *Historia Augusta* Indeed, his ability to deal with multiple conflicts properly must be praised.

Marcus Aurelius – Shaped by Stoicism

Marcus Aurelius' political actions find their roots in Stoic philosophy. In his *Meditations* Marcus mentions the paternal affection that he was shown. By all accounts, Romans viewed him as a fatherly⁴³ figure in his administration of the state.⁴⁴ Most importantly, he raised his brother Lucius Verus to co-emperor. This shows that Marcus understood the political situation at Rome. The Roman Empire needed to have leaders who could deal with issues on multiple fronts.⁴⁵ Marcus became the first emperor to appoint a co-ruler and rule the state as two. Marcus showed loyalty when he chose to support his brother despite Verus' lifestyle of excess. In this way, Aurelius demonstrates loyalty like Caesar or Alexander. Caesar demonstrated loyalty to his legions by giving them both land and wealth that he promised in return for their faithful service. The Roman state came to be ruled by a tetrarchy one century after Marcus' death. Much of the intervening time came to be known as the Crisis of the Third Century. One of the reasons for the ensuing chaos was the inability of the central government to deal with problems over such vast swath of land. Subsequent emperors struggled to realize what Marcus understood, that the Roman Empire was far too big and complex to be ruled by a single emperor. Multiple rulers were needed to govern properly.

Marcus Aurelius' personal life also was shaped by his belief in Stoic philosophy. The difference between the life of Marcus and those of Alexander and Caesar is plain to see. Marcus' way of life is simply condensed in a quote of his from his *Meditations*. He

³⁹ Cassius put down the revolt in 172 CE. Imperium gives a Roman commander the power to choose life and death over those under him. Both Julius Caesar and Augustus were voted this power honorifically, which was held by every emperor thereafter.

⁴⁰ *Historia Augusta: Life of Marcus Aurelius*, 24.6-12.

⁴¹ *Historia Augusta: Life of Marcus Aurelius*, 17.1-3

⁴² *Historia Augusta: Life of Marcus Aurelius*, XII.2

⁴³ *Historia Augusta: Life of Marcus Aurelius*, I.1-3

⁴⁴ Marcus Aurelius, *Meditations* (trans. by C.R. Haines), *Loeb Classical Library*

⁴⁵ *Historia Augusta: Life of Marcus Aurelius*, VII.4-5

states “There is nothing better than for a man to confine himself to necessary actions.”⁴⁶ Marcus Aurelius did not take in excessive pleasures or act rashly, much like Caesar. He administered justice with sobriety and did not adhere to rumors. Of the three leaders, Marcus’ personal life was the most restrained, meaning that he did not suffer the same type of consequences that Caesar and Alexander did.

Marcus clearly is linked to Alexander as a giant of antiquity. As Marcus was dying, he echoed the lament of Philip II of Macedon, Alexander’s father, stating that he was grieved to have left behind a son. While the fate of these sons is completely different, the linkage is clear. Marcus’ son Commodus’ reign swiftly ended the so-called Five Good Emperors. Philip’s son Alexander did precisely the opposite through his conquest of Asia. Explicit references show that Marcus also thought about comparison with Alexander. Aurelius mentions that both Alexander and the man who packed his mules face the same bodily decomposition in death.⁴⁷ This fact demonstrates that Marcus recognized his greatness but also thought of greatness as a fleeting concept, which is reasonable due to the influence of Stoicism on his life.

Conclusion

Alexander, Caesar and Marcus Aurelius demonstrated greatness in their lifetimes. This study has determined some of the traits necessary for being a good leader and established a linkage between Alexander the Great and two leading Romans. Both Julius Caesar and Marcus Aurelius made efforts to follow the positives of Alexander’s character while attempting to avoid negative aspects. In the end, Caesar took clear actions in imitation of Alexander. Marcus Aurelius seemed to avoid comparison when possible but certainly shows that Alexander was thought about by Roman emperors of the time. In fact, Marcus’ son Commodus often pretended to be like Hercules and Alexander, wearing ⁴⁸ lion skin. Alexander traced his lineage through Hercules and portrayed himself as his equal. Finally, whether leading Romans imitated the greatness of Alexander or not, his mere presence centuries later speaks volumes. It is reasonable to state that Caesar and Marcus Aurelius were both tangibly influenced by Alexander, even though that influence manifested itself in very different ways.

⁴⁶ *Meditations*, bk. IV.20.

⁴⁷ *Meditations*, bk. VI. 22.

⁴⁸ The lion skin refers to one of Hercules’ labors in which he defeated the Nemean Lion, an impossible task.

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Tulpamancy: A closeted community of imaginary-friend hobbyists

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Abstract

Social deviance often poses a barrier in socialization, as participation in deviant practices can be difficult to disclose to others. Despite these challenges, in recent years Internet communities that revolve around socially deviant practices have taken shape. This study looks into the Tulpamancy community, a relatively new online community of mainly adults who partake in creating seemingly sentient, autonomous hallucinations. These hallucinations, or ‘Tulpas’ typically serve as companions in participants’ everyday lives, and in many cases resemble an imaginary friend that can be perceived in reality. The study looks into who commits to this practice, as well as when, how, and why current community members have joined. Through doing so, it intends to speak to the factors that drive individuals to join and maintain deviant online communities. The study finds real-life factors such as loneliness to have influence on willingness to join the community and commit social deviance.

Introduction

A small group of adults with dreams of interacting with My Little Pony characters have created a new subculture in recent years. They have successfully created a community of adults that conjure up seemingly autonomous imaginary friends of all kinds through the use of ancient Tibetan Buddhist meditative practices. It has grown to a membership of over 20,000, while keeping their community rather unknown to society at large. How can a community centered around such unusual practices come to stand on its own and attract so many members, while remaining largely unknown to the public?

This community, known as the Tulpamancy community, has been able to form and maintain itself by means of the Internet. These “Tulpamancers” have dodged the obstacles of social and spatial constraints by forming their community almost exclusively online, allowing for it to prosper without confronting taboo. The concept of Tulpamancy was introduced to the Western world in 2012 as a small circle of individuals on 4chan: an anonymous forum-like imageboard. Since its initial debut to Western society, the community has grown into a major sub-culture with over ten thousand members virtually unaffected by the taboo of creating an imaginary friend

(Veissière, 2015). Though it's clear that the Internet played a major role in this community's success, many questions remain about what key aspect of the Internet allows for socially deviant communities such as this one to prosper.

Previous research into anonymous communication has brought forth findings such as the Social Identity model of Deindividuation Effects (SIDE) – a model describing how anonymity can influence human behavior (Reicher et al., 1995). Anonymity certainly plays a key role in this community's success, however it is not the only factor which possibly contributes to the inception and maintenance of this socially deviant community. Other factors may come into play that allow for communities centered around social deviance to take shape, such as the lack of need for face-to-face communication, close geographic proximity, or local interested individuals. Additional social factors may also be at play, influencing one's willingness to participate as well as to maintain the community.

This study seeks to provide insight into how socially deviant Internet communities form, through looking into the Tulpamancer community in particular. Within this study, I do not directly test competing explanations of internet sub-culture creation, but rather look into this sub-culture's online interactions, history, and experiences to shed light on factors that shape deviant Internet communities' formation and maintenance. Additionally, the study seeks to bridge gaps of knowledge related the Tulpamancy community itself, as well as the implications that socialization with these imaginary friends has on an individual, as well as other groups.

Background

The history of Tulpamancy dates back to ancient times, as a practice in ancient Tibetan Buddhism (Melton, 2001). Monks in the Vajrayana esoteric tradition would create Tulpas to overcome their fears (Veissière, 2015). Though it remained a practice solely in Tibet for many thousands of years, it was eventually brought to the West due to exploration in the Tibetan region. Both Veissière and Mikles, two anthropologists describe the explorer Alexandra David-Neel's exposure to the concept in 1929, during her journey to Lhasa, Tibet (Mikles, 2015; Veissière 2015). It is written that she explored the concept of Tulpamancy for her own purposes, rather than using it as a means to overcome a fear. Instead, Veissière and Mikles describe the explorer having used those techniques to create an autonomous Friar Tuck Tulpa from Robin Hood, as a companion (Veissière, 2015).

Veissière describes the modern re-appropriation of David-Neel's findings on the Internet, on 4chan's /mlp/ (My Little Pony) board. Here, Bronies attempted to use David-Neel's methods to create a fully autonomous pony within one's imagination, with the focus of creating an imaginary friend that they could perceive in reality (Veissière, 2015). Since then, both Veissière and Mikles have described a shift from Tulpamancers remaining primarily on 4chan's /mlp/ board, to founding their own communities (Mikles, 2015; Veissière, 2015). It has since led to the creation of the /r/Tulpas page on Reddit, as well as the websites Tulpa.info, and Tulpa.io, the three of which have reached over 21,901 registered accounts.

The demographics of these modern Tulpamancers are described as white, middle-class youth, of whom most are undergraduate university students, though up to 1/3 are fully employed

(Veissière, 2015). In his surveys, Veissière also asked about the Tulpamancer's gender, which he reports has a male to female ratio of 3, while up to 10% of the population identifies as some degree of gender fluidity (Veissière, 2015).

In his study, Veissière found that most Tulpamancers report loneliness and social anxiety, and that many report that they started Tulpamancy to address these issues (Veissière, 2015). He goes on to propose improvements in the lives of those who have struggled with socialization, as well as mental illnesses aside from anxiety disorder (Veissière, 2015).

As for the Tulpamancy community itself, in the English-speaking world, Tulpamancy sites consist primarily of the /r/Tulpas subreddit and the Tulpa.info and Tulpa.io forums (Veissière, 2015). However, Veissière has noted that there are many other sub-communities where other languages are employed (Veissière 2015). His findings show that over half of the Tulpamancy community globally resides in those three English-language communities, while Tulpamancy websites in other languages remain dispersed throughout the Internet (Veissière, 2015).

Although information of where current Tulpamancers reside in cyberspace is well known, there are still gaps in knowledge about where many of these individuals come from. Though the concept spawned from 4chan's /mlp/ board, contemporary Tulpamancers within the online community more often than not have joined the community after the inception of sub-communities such as r/Tulpas and Tulpa.info. The community migrated to these sites to create a permanent home for Tulpamancers, rather than the quick, temporary communication which 4chan provides. The majority of the community began Tulpamancy after the subculture shifted from 4chan to their own independent sites, and thus the current population has gotten into the hobby from many websites other than 4chan.

Within each of the sub-communities, the general beliefs and practices remain the same. Though not a mental illness, Tulpamancy shares similarities to Dissociative Identity Disorder, in the sense that in both cases, the whole concept of interaction hinges on the idea that each personality is another person (Kihlstrom, 2005). The Tulpamancy community and practice also rely on the idea that Tulpas are real people within the mind, and participants interact with their Tulpas the same as they would with other human beings (Veissière, 2015). This core idea as well as the main practices of Tulpamancy remain consistent in each of the communities throughout the world, often diffusing outward from the English sub-communities (Veissière, 2015). Additionally, Tulpamancers are increasingly creating smaller, more intimate groups to discuss day-to-day findings and experiences; however, little is known about the mediums by which this is conducted.

The Tulpamancy community is a closeted Internet community, sustained and rooted in the concept of anonymity. For the most part, all interactions within this community are anonymous, and only a small few ever mention their practice of Tulpamancy to members of their social circle in real life. This is likely because the practice of Tulpamancy is considered socially deviant, and is quite difficult for outsiders to understand. Under ordinary circumstances, such a community would be more difficult to form in reality, due to the social deviance related to creating an 'imaginary friend' as an adult. But online, this is not the case.

An online community can easily take shape for a number of reasons, one being that members are all anonymous. In accordance with the SIDE model, the Tulpamancy community demonstrates a willingness to openly discuss and encourage participation in these socially deviant acts, that otherwise would be difficult to encourage – were the community to exist entirely offline (Reicher et al., 1995; Quinn et al., 2013). Other deviant online communities have been able to form and maintain themselves with ease for these same reasons, as members have felt more comfortable participating in deviant activity in part due to remaining anonymous throughout communication. This has been observed in other deviant online communities, such as the White Supremacy community, a community of which many describe as their “second home” (Douglas et al. 2005).

Online white supremacist groups who commit deviant acts through cyberhate and terrorism recruit new members and incite deviance through virtual means (Levin, 2002). While sharing no similarities in ideology, the Tulpamancy community and the White Supremacy community exhibit similar traits with respect to membership and maintenance of the community. Both communities are able to incite and promote socially deviant acts, as a basis for their own ideologies and values (Douglas et al. 2005; Veissière, 2015). The SIDE model suggests that through anonymity, these two communities have been able to incite and promote socially deviant acts, due to the lack of use of identities online. It is therefore suggested that anonymity plays a role in Tulpamancers’ willingness to join and participate, and may be observed by looking through members’ willingness to divulge their participation in this community with peers in reality. This, coupled with offline social struggles driving online participation, is one of the many possible factors that influence participation within these communities (De Koster et al., 2008; Veissière, 2015).

Additionally, community members are not burdened by the distance between each member, possibly furthering the ease of this community coming together and developing its own set of values and principles. Existing almost entirely on the Internet also allows for the community to easily validate their own values without facing any sort of social backlash (Quinn et al., 2013). Similar characteristics can be observed with other communities that partake in socially deviant behavior, like this community’s relative, the Brony community (Veissière, 2015).

Bronies, like Tulpamancers are drawn to their practice primarily out of loneliness, and seek positive interaction (Robertson, 2013; Veissière, 2015). The positive messages from a television show geared toward young girls fulfills the need for interaction, which Bronies often lack due to social anxiety, and provide an experience and lifestyle among community members worth discussing (Robertson, 2013). Bronies found their home in anonymous websites, such as 4chan, due to the nature of absolute anonymity on the site (Robertson, 2013). Without faces and names tied to each individual, this community of mainly adult men were able to successfully create and sustain a community centered around a socially deviant practice.

From Bronies shrouded in anonymity came the Tulpamancer community, who experience similar communal traits with aspect to anonymity and other internet-related factors (Veissière, 2015). Without the need for face-to-face interaction, the Tulpamancy community too has succeeded in growing to a massive size, while remaining relatively unknown to the public. It is entirely possible that the Tulpamancer community and the Brony community are sustained by similar factors at play, involving young adults and socially deviant practices. Through studying groups

such as these, much can be learned about the driving factors behind membership of deviant online communities, and it is important to learn as much as possible about them to understand more about how groups can form without an identity tied to each individual.

Methods

This study takes a variety of approaches in looking into the Tulpamancy community. It consists of two surveys that have been distributed to three major Tulpamancy websites. The first survey seeks to answer demographic questions about respondents, such as the participant's race, gender, and country of origin, as well as other questions regarding their daily life and their practice of Tulpamancy.

I request respondents' email addresses at the end of the first survey, which I use to send them a second, more in-depth and qualitative survey if they consent. The second survey consists of much more extensive questions about the respondent's practice of Tulpamancy, as well as their daily lives, and is made up of primarily short-answer questions. This two-stage design was implemented not only to maximize participation within the first survey, but also to minimize the amount of time needed to complete each section. This method also ensured maximum completed survey results, as participants spent about one full day between the first survey and the second.

Sampling

I made posts on each of the three Tulpamancy sub-communities – /r/Tulpas (a sub-reddit on reddit.com), Tulpa.info and Tulpa.io (two independent sites) – recruiting future participants into the study. Each post describes the study (see appendix A), as well as a link to the initial survey. As Veissière indicated in his study, these three sites serve as the primary virtual locations at which Tulpamancers congregate, and thus the survey has been made publicly accessible to anyone who visits these sites (Veissière, 2015). Sampling includes all members of the community, including those who do not have a Tulpa, but participate in the community. In both the first and second surveys, responses are filtered based on whether or not the respondent has a Tulpa, and asks specific questions based on these two situations.

Data

This study utilizes survey responses from two surveys about community members' practices, collecting data from sets of multiple choice questions, 'select all that apply' questions, and free response questions. Using the survey responses, I look into who and what this community is, and the implications of being a member of this community.

Research Method

This study takes a mixed-methods approach, with hope to find explanations for a number of questions about the Tulpamancy community. By comparing the two types of survey responses, as well as analyzing publicly available posts and resources created by the community, I hope to find links between the publicly expressed opinions and disclosed responses to the surveys in order to develop theories inductively. Through doing so, previously unknown linkages between the Tulpa experience, and social factors may be exposed. The questions explored through comparison and inductive analyses include:

- The demographic characteristics of community members
- Driving factors behind participation in this deviant community
- How sociability affects participation in the practice
- How community members perceive their socially deviant practice
- Parent communities promoting interest in the practice
- General citizenship of other communities
- Community participation mediums
- Community retention time

To answer questions about the demographics of practitioners of Tulpamancy, I've provided a number of questions in the first survey about members' countries of origin, racial and gender identification, educational attainment, and others (see questions 1 through 10 of Survey A). From these responses, we can see what demographic groups take interest in the practice, and community.

To understand some of the driving factors behind participation in this community's socially deviant practice, I have chosen to include a short answer question in the second survey, asking why they are interested in creating a Tulpa (see question 18 of Survey B). These responses may potentially include thoughts, feelings, hesitations, and perceived benefits of creating a Tulpa – things that are not easily captured through typical survey questions. Such findings may assist in the development of theories as to why Tulpamancers choose to partake in this practice, as well as the community.

To better observe how social factors affect participation in the practice, factors related to sociability have been analyzed with respect to those who actively participate in Tulpamancy and those that do not. These observed variables include responses to questions regarding social ease, shyness, and friendship, coming from questions worded as “Is it easy for you to speak up in social situations?”, “Would you describe yourself as more shy or outgoing?” and “Would you say that you have a lot of friends outside of the Internet?”. These questions were asked on a four-point scale, ranging from very negative responses to very positive responses (see questions 38, 39, and 40 of Survey A). Through the analysis of these factors, offline influences may be observed, altering online behavior and deviant behavior within this community.

To examine how the community perceives the practice of Tulpamancy, I have also included questions regarding how Tulpamancers perceive their peers' views of their deviant practice, to better understand how social deviance can play a direct role in the practice (see questions 16 and 17 of Survey A). By looking into the community's self-identifying values as well as their perception of the taboo itself, theories regarding how deviance affects a community's function and role can be developed.

To learn about other sites and mediums by which members communicate, respondents were asked to describe other mediums that they personally use to partake in community participation. Through analysis of these responses, a clearer description of the structure of this community can be observed (see question 20 of survey A)

To see what other online communities Tulpamancers are a part of, a question in the first survey is asked, requesting that the respondent outline their other typical Internet dwellings (see question 21 of Survey A). Trends among certain common websites that these individuals browse may provide further insight into the types of people who choose to become members of these communities. Analyzing these factors may develop theories related to how other Internet habits and interests contribute to the willingness to commit social deviance, and join online communities.

Finally, to articulate how long average Tulpamancers have been a part of the community, respondents have been asked to indicate the amount of time since they have first been in practice (see question 13 of Survey A). By looking into this description, we can gauge the level of experience among members within the sample.

Results

Demographics

Table 1: Basic demographics among participants.

Variable	N	Mean	SD
Age	160	22.1	5.02
Gender			
Male	103	62.8	-
Female	29	17.7	-
Other	32	19.5	-
Race			
White	120	73.6	-
Black	1	0.6	-
Hispanic	12	7.4	-
Asian	17	10.4	-
Multiracial	11	1.2	-
Other	2	6.8	-
Country of origin			
English-speaking countries	124	76.07	-
Other countries	39	23.93	-
Religious	45	27.4	-
Currently in school	84	51.2	-
Enrollment among students			
High school	17	20.2	-
University	63	75	-
Graduate study	4	4.8	-
Academic achievement level among not in school			
Less than high school	12	15.4	-
Graduated from high school	16	20.5	-
Completed 4-year degree or more	22	28.2	-
Full-time employment	32	59	-

Findings suggest that the average member of this sample is about 22 years old. Table 1 reports the average age for all community participants, both those who identify as Tulpamancers and those who do not, known in the community as ‘Singlets’. Additionally, the table contains a breakdown of age based on whether or not the respondent is in fact a Tulpamancer. Results remained at an average of roughly 22 years of age. Of participants surveyed, most hailed from English-speaking countries, with the United States, United Kingdom, Canada, and Australia making up 76.07% of the sample. However, over 20 countries of origin are found within the sample.

When looking at the gender breakdown of this community, it was found that 62.8% of respondents identify as male, while 17.68% identify as female. Additionally, 19.51% of respondents chose not to identify as male or female, or chose to identify as some form of transgender.

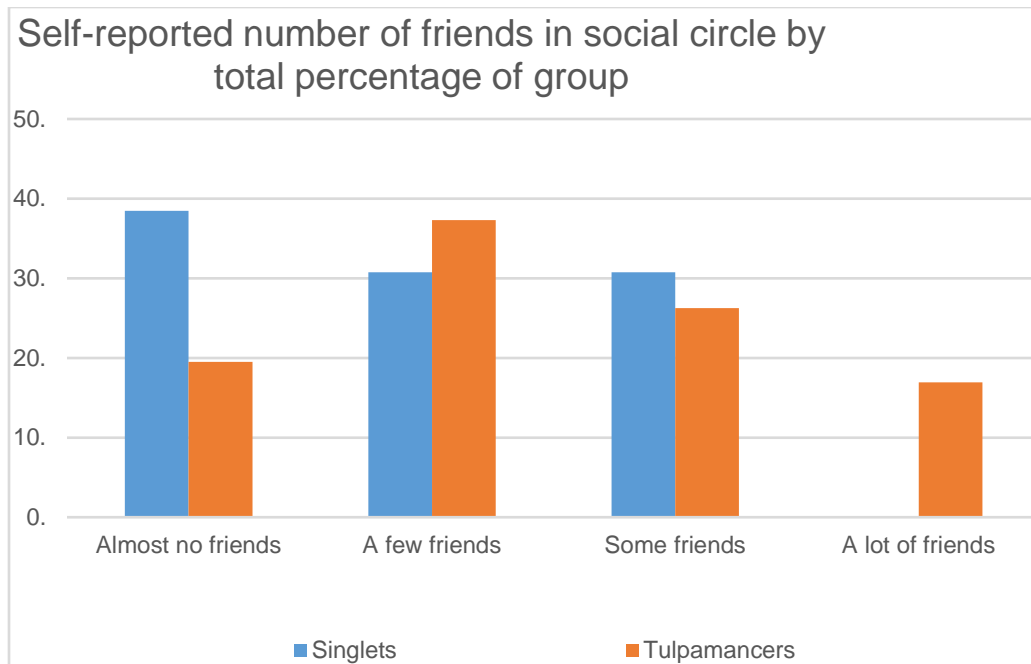
When looking at the ethnic makeup of the sample, findings show that the majority of participants identify as White. Almost no respondents identified as black, and there was non-trivial representation of other groups.

From these demographical insights, it can be inferred that members of this community are predominantly white, college-aged young adults, the majority of whom identify as male. Additionally, many respondents are identified as unemployed, or have dropped out of college, possibly suggesting struggles with societal adjustment among this population.

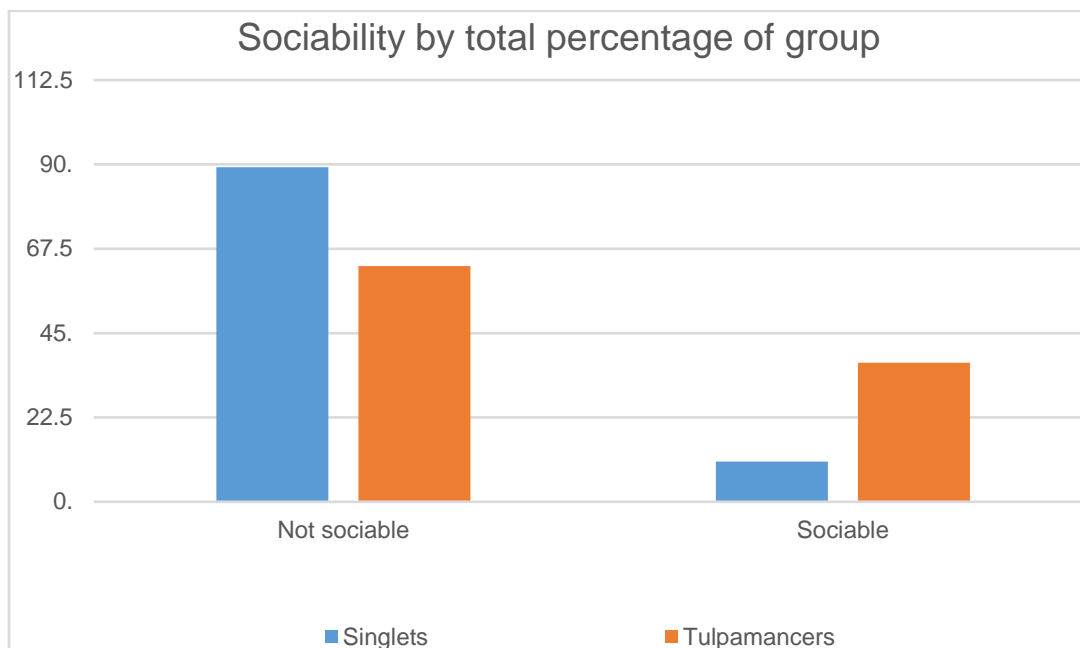
Factors promoting participation in Tulpamancy

Analyses of responses from community members that are not Tulpamancers, yet want to become Tulpamancers, has shown many trends in responses, particularly when asked why the respondent would like to make a Tulpa. The majority of responses to this open-ended question involved a longing for a friend and for companionship, suggesting that respondents without Tulpas seek socialization, and an escape from loneliness. For instance, one respondent wrote that they originally chose to commit to this “out of desire for a companion” and “out of loneliness”.

I ran two tabulations on singlets’ levels of loneliness, and indicators of Tulpamancers’ levels of loneliness. Although having friends does not guarantee that one is not lonely, it does indicate it to be less likely. Perhaps surprisingly, this survey shows that Tulpamancers have more friends on average than singlet members of this community.



I did another set of tabulations, combining the number of perceived friends respondents had, perceived levels of shyness, and social ease into a sociability variable. The three four-point variables were summed to form a single twelve-point sociability variable. Respondents were regarded as not sociable if their combined score resulted in less than 9 of the 12 possible total points between the three sociability variables.



Findings further suggest that through participation in this socially deviant practice, participants are able to improve their own sociability. This lines up with Tulpamancers' responses within the survey, in which a number of respondents cited becoming more social as one of the benefits they

have achieved from Tulpamancy. For example, one respondent stated that through engaging in this practice, their Tulpa has “saved my social life for sure”, through “giving mental support and advice”. Another writes that by creating a Tulpa, they have been helped “set up relationships (of all kinds) that wouldn’t have happened otherwise”.

Perception of practice

Within the first survey, Tulpamancers were asked for their perception of how their peers would react if they knew that they committed to this deviant practice. Among Tulpamancers who could determine how their social circle would react knowing this, 69.44% stated that they believe that their peers would react negatively.

Table 2: Perceived peer reaction to learning of participants’ deviance.

	N	Percent of sample
Positive reaction	22	30.6
Negative reaction	50	69.4

Thus, Tulpamancers believe that they would suffer social consequences if their practice was exposed to their peers, suggesting that Tulpamancers recognize that this is a deviant practice subject to social sanction.

Analysis of who within Tulpamancers’ social circle is aware of their practice was conducted in order to gauge how many Tulpamancers had exposed themselves to their peers. Findings show that 49.64% of respondents have told no one – not acquaintances, friends, or family that they commit to this practice.

Table 3: Peer awareness of participant’s deviance.

	N	Percent of sample
Peers aware of practice	69	51.4
Peers unaware of practice	68	49.6

These findings may serve implications in the development of the community, and highlight the importance of this community’s grounding in the internet rather than physical reality.

Parent communities

In the second survey, respondents were asked to identify how they had first heard about Tulpamancy. Though some respondents indicated that they learned about the practice through an online or offline friend, many respondents learned about the practice through particular websites. Table 4 displays a breakdown of the sites of which Tulpamancers have come from.

Table 4: Internet communities by which respondents first learned about Tulpamancy.

	N
420chan	1
Kik	1
Reddit	12
4chan	10
Tumblr	4
DeviantArt	1
(Total number of respondents)	29

Findings suggest that the majority of respondents heard about the practice through reddit.com; however, findings may be skewed due to most of the sample already being members of the site.

Citizenship of other communities

Participants were asked to also describe other websites of which they are members of, unrelated to Tulpas. Using this data as a map, one can peer into the type of sites of which these Tulpamancers hail from, giving insight into Tulpamancers' character as well as underlying factors that may drive them to take part in a deviant online community.

Table 5: Participants' other Internet browsing dwellings.

	N
furaffinity.net	15
deviantart.com	23
tumblr.com	40
4chan.org	24
reddit.com	99
(Total number of respondents)	114

Findings display a strong affinity for reddit.com, despite Tulpamancy's origins on 4chan. However this is likely due to one of the major Tulpamancy sub-communities being held on this site at /r/Tulpas.

Community participation mediums

The first survey included a question asking for respondents to describe other mediums by which they participate in the community. Results in table 6 provide a more accurate representation of communication mediums within the Tulpamancer community.

Table 6: Mediums by which Tulpamancers communicate.

	N
/r/Tulpas	104
Tulpa.info	45
Tulpa.io	29
Tulpa-related IRC channels	26
Tulpa-related Skype groups	20
4chan	9
Tulpa-related Kik chats	2
(Total number of respondents)	128

Findings show that Tulpa discussion still occurs on 4chan in modern times. From write-in responses, it has been observed that members of the community participate in 4chan's new /trash/ board, in which they have Tulpa discussions fragmented from /r/Tulpas.

Community retention time

In the first survey, Tulpamancer respondents were asked how much time has passed since they first became a Tulpamancer. Findings were as follows:

Table 7: Time passed since first engaging in practice.

	N	Percent of sample
1 month	2	1.6
3 months	6	4.7
6 months	13	10.2
12 months	25	19.7
24 months	26	20.5
36 months	28	22
48+ months	27	21.3

Findings suggest that a majority of the sample contains respondents who have been members of this community for a long time, suggesting that much of the community consists of more experienced practitioners.

In addition, Tulpamancers' rates of participation were also measured.

Table 8: Rate of community participation among participants.

	N	Percent of sample
Daily	42	33.3
Every few days	28	22.2
Weekly	9	7.1
Every now and then	28	22.2
Hardly ever	19	15.1

Findings suggest that the majority of the sample participates periodically, implying that other Tulpamancers who do not participate as frequently through the three sites may primarily participate through the other mediums described.

Discussion and Conclusion

The results from this study suggest that this is a community of primarily white, college-aged individuals who have flocked to this practice both out of curiosity and as a means to escape loneliness. The majority of respondents have indicated that they struggle with social engagement, creating friendships, and being outgoing – coinciding with Veissière’s reports within his study (Veissière, 2015). Additionally, it has been observed that these feelings of loneliness and struggles with socialization are more apparent among respondents who do not yet have Tulpas but take interest in the practice and are members of the community. Such findings could potentially suggest that with the practice of Tulpamancy, one’s perceived sociability increases; however, strong evidence of a causal effect is lacking. It is entirely possible that other factors may contribute to the discrepancies between individuals with and without Tulpas in this community. Additionally, singlet members of the community likely differ from the general population of singlets, resulting in findings demonstrating changes in sociability only within the scope of this community. To look into how this practice affects an individual’s sociability, further analyses would have to be conducted, comparing individuals outside of the community to those within it.

Results demonstrate one of the many possible reasons why individuals begin to partake in this practice. However, to look further into the reasons why Tulpamancers commit to Tulpamancy, other factors must be isolated and more detailed information must be collected about the circumstances that have brought participants to join this community and commit to this practice. Through the means of in-depth, direct interviews of community members who have just started their practice, moderately experienced Tulpamancers, and advanced Tulpamancers, deeper insight can be obtained as to the factors that attract members, as well as what pushes them to continue with the practice.

Future research may also benefit from observing the genderqueer population of respondents within this sample. Over 19% of respondents either identified as transgender or neither male nor female – a staggering number compared to those within the general population. By peering into

the conditions that affect non cisgender conforming communities, it is possible that some explanations as to why many respondents identify in such a way can be uncovered. Findings from future research into this particular demographic within this community may reveal certain factors within community members' personal lives that drive them to join this community and commit to this practice.

With a deeper look into the factors that bring community members toward participation, and through the contrast of other deviant online communities, theories about what drives the sustainability of deviant online communities can prosper. From the data collected within this study, loneliness and social difficulty has played a major role in respondents' decisions to join, but other latent factors may influence members' drive to participate.

Limitations

This study involves only respondents over the age of 18 due to IRB-related constraints. For this reason, members of the community have not entirely been represented. Future studies should seek to include all members of the community, to improve accuracy. Additionally, this study has been limited by responses being exclusively self-reported data, as well as has been restricted by its small sample size. Moreover, the sample consists of participants who have selected themselves as participants in the study, yielding more passionate members of the community than would be representative. Lastly, the majority of respondents are those who have been participating in the community for over one year.

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Appendix A

Survey A recruitment instrument

TITLE: Tulpamancy Research

TEXT:

Hello all!

I am an undergraduate sociological researcher who is studying the Tulpamancy community and phenomenon from a sociological perspective. I am fascinated by the concept and community of Tulpamancy. Like others before me, I want to illuminate this phenomenon and group to the research community, leading to greater understanding of this group. To do so, I am collecting original data about the experiences of Tulpamancers and members of this community that do not have Tulpas. Would you be willing to help me out?

If so, I've created a short, five-minute survey to fill out. To participate, you must be 18 or older. If you are younger than 18, unfortunately you cannot participate, and your data will not be used even if you submit anyway.

Additionally, at the end of the survey it will ask for your email address. You absolutely do NOT have to supply your email address if you do not feel comfortable. However if you do so, you will be sent an email with a link to a second, more in-depth interview. This could take between 5 and 20 minutes to fill out, depending on how much detail you'd like to supply.

If you fully consent to participating in this anonymous study, or have received parental permission to participate in it, please affirm this by clicking the link below and beginning the first survey:

[Survey link]

Thank you for reading this. I look forward to learning more about Tulpamancy and the community, and I hope that I can assist the community by bringing that knowledge to light.

If you have any questions, please send me a private message, or email me at [Email address].

Survey B recruitment instrument

Subject: Tulpamancy Research Follow-up Survey

Text:

Hello,

Thank you for completing the first Tulpamancy survey and supplying us with your email address. The second, more in-depth survey is now available for your response. This survey consists almost exclusively of short-answer questions, and could take 5 to 20 minutes of your time, depending on how extensively you choose to fill out the survey. Additionally, at the end of the survey you will be asked to supply your email address a second time, so that we can link your responses in the second survey to the responses you made in the first survey. You are *not* required to supply us this information a second time if you do not consent. Your responses are completely anonymous, so if you do not feel comfortable with linking your responses in the second survey to the first survey, you can choose not to respond.

If you hereby consent to participating in the second and final portion of this anonymous study, and have received parental permission to participate if you are younger than 18, then please indicate so by clicking the following link and filling out the survey:

[Survey link]

Thank you for your assistance.

Appendix B:

Survey A data collection instrument

The following questions refer to 'you' as the host.

1. How old are you?
2. What country do you live in?
3. What is your gender?
 - Male
 - Female
 - Male (Trans)
 - Female (Trans)
 - Other (please specify)
4. What is your race/ethnicity? Mark all that apply.
 - White
 - Black
 - Latino
 - East Asian
 - South-east Asian
 - Middle Eastern
 - Pacific Islander
 - Other (please specify)
5. Are you religious?
 - No
 - Yes (please specify your religious preference)
6. Are you currently enrolled in school?
 - Yes
 - No
7. What level of school are you currently enrolled in?
 - Less than high school
 - High school
 - University
 - Graduate study
8. Do you also have a job?
 - No
 - Yes (please specify current employment)

9. What is the furthest you've gone in school?

8th grade or less

9th-12th grade

High school graduate

GED

Attended college but did not graduate

4-year degree

Advanced degree

10. Are you currently employed?

No

Yes (please specify current occupation)

11. Have you created a Tulpa before?

Yes

No

12. How many Tulpas have you created?

13. How long have you been a Tulpamancer?

Less than 1 month

Less than 3 months

Less than 6 months

About 1 year

About 2 years

About 3 years

More than 4 years

14. How many hours a week do you active force? (Force in the Mindscape)

1-3 hours

4-7 hours

8-14 hours

More than 14 hours

I don't consistently active force

I don't active force

15. How many hours a week do you passive force? (Force in reality)

1-3 hours

4-7 hours

8-14 hours

I constantly passive force

I don't consistently passive force

I don't passive force

16. In real life, does anyone know that you have a Tulpa?
Family
Close friends
Acquaintances
17. If your family, friends, or acquaintances knew that you have a Tulpa, would they react well?
They would react positively
They would react negatively
I don't know
18. Do you have other Tulpamancer friends online?
Yes
No
19. How often do you come to this site to interact with the community?
Daily
Every few days
Weekly
Every now and then
Hardly ever
20. Which Tulpa-related groups are you a part of?
/r/Tulpas
Tulpa.info forums
Tulpa.io forums
Tulpa-related IRC Channels
Tulpa-related Skype groups
Tulpa-related Kik chats
Other groups (please specify)
21. What other sites do you regularly visit?
Reddit (Outside of /r/Tulpas)
4chan
Tumblr
DeviantArt
FurAffinity
Other (please specify)

22. What is your [first] Tulpa's current form?
- Humanoid
 - Semi-humanoid
 - Anthropomorphic animal
 - Pony
 - Animal
 - Mythical creature
 - Robotic
 - Has not attained form
 - Other (please specify)
23. Was it mostly you, or your Tulpa that decided their appearance?
- I mostly decided their appearance
 - They mostly decided their appearance
24. How many times has your Tulpa drastically changed their physical appearance?
25. What is your Tulpa's gender?
- Male
 - Female
 - Agender
 - Other (please specify)
26. What basic skills is your Tulpa capable of?
- Mindvoice speech
 - Fluent speech
 - Visualization within the mindscape
 - Thought/Word distinguishment
 - Reality imposition
 - Basic possession
 - Full-body possession
 - Switching
 - Parallel Processing
 - Total imposition (All senses)
27. Is there anything else we should know about your Tulpa's abilities?
28. Do you like your Tulpa's personality?
- Yes
 - No
 - I neither like it nor dislike it
29. Was it mostly you, or your Tulpa that influenced their personality?
- I mostly influenced their personality
 - They mostly influenced their own personality

30. Do you have a good relationship with your Tulpa(s)?
We have a good relationship
We don't have a relationship
We have a negative relationship
31. How intimate do you feel your Tulpa/Host relationship is?
Less intimate than any human relationship
As intimate as an acquaintance relationship
As intimate as a friend relationship
As intimate as a family relationship
As intimate as a romantic relationship
More intimate than a romantic relationship
32. Have you ever chosen to spend time with your Tulpa(s) over spending time with another human?
Yes
No
33. Do you feel it is easier to communicate with your Tulpa(s) than other humans?
Yes
No
34. Have you ever felt pressured to spend time with your Tulpa(s)?
Yes
No
35. Have you felt decreased loneliness since creating your first Tulpa?
Yes
No
36. Do you have any other Tulpamancer friends online?
Yes
No
37. Do you have any other Tulpamancer friends offline?
Yes
No
38. Is it easy for you to speak up in social situations?
Very difficult
Difficult
Easy
Very easy

39. Would you describe yourself as more shy or outgoing?

Very shy

A little shy

A little outgoing

Very outgoing

40. Would you say you have a lot of friends outside of the Internet?

I have almost no friends

I have a few friends

I have some friends

I have a lot of friends

41. Has a doctor diagnosed you with any of the following mental/emotional conditions?

ADD/ADHD

Autism (Including Asperger's Syndrome)

Depression

Anxiety Disorder

Bipolar Disorder

Schizophrenia

Dissociative Identity Disorder

Other (please specify)

Survey B data collection instrument

The following questions refer to 'you' as the host.

1. Do you have a Tulpa?

Yes

No

2. Do you believe that your Tulpa has achieved sentience?

Yes

No

3. How long ago do you believe your Tulpa has achieved sentience?

4. How did you know your Tulpa was sentient?

5. How did you first hear about Tulpamancy?

6. How did you feel about the concept before you tried it?

7. What's your [first] Tulpa's name?

8. Describe your Tulpa's current physical appearance.

9. What is your Tulpa's personality like?

10. Why did you make a Tulpa?

11. How has your Tulpa(s) helped you in life?

12. How close/intimate is your relationship with your Tulpa?

13. How have/would your family and friends react to you having a Tulpa?

14. What are some things that Tulpamancy has helped you do? (i.e. better at drawing, better sleep, etc.)

15. What are some ways that Tulpamancy has hurt you? (i.e. unwanted hallucinations, nightmares, etc.)

16. What do you like about the Tulpamancer community?

17. What do you dislike about the Tulpamancer community?

Geochemistry and metal release from Marcellus Shale and surrounding rock formations

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Abstract

High total dissolved solids as well as high concentrations of anions and alkaline earth metals (Cl, Ba, and Sr) are contaminants of concern in wastewaters produced from unconventional oil and gas wells. These contaminants are thought to originate from migrated formation brines and/or shale mineral dissolution and mixing with hydraulic fracturing fluids. Understanding intra- and inter-geologic unit metal composition and contaminant release is important in assessing the origin of produced oil and gas wastewaters. To study intra- and inter-geologic unit metal composition, Marcellus Shale samples, Utica Shale samples, and their overlying and underlying confining units were collected from multiple cores at varying depths (428-5163 ft. below ground surface). Samples from surrounding formations, i.e. Salina Group, suspected of hosting the original brine that subsequently migrated into other units were also collected. Samples were characterized by sequential extractions. Extractant solutions were analyzed for anions (IC) and cations (ICP-MS). Marcellus Shale and Utica Shale samples should experience similar elemental mobilization since they may receive migrated formation brines from the same rock formation, the Salina Group. Rock dissolution and mixing with hydraulic fracking fluids may play a larger role in high elemental mobilization than formation brines. Interestingly, Utica Shale samples experienced more elemental mobilization than Marcellus Shale samples in anions and cations such as Br, Cl, and Na.

Introduction

Unconventional oil and gas production is steadily growing in the United States due to the use of directional drilling and hydraulic fracturing techniques. Natural gas is pursued for several reasons, such as the reliability of U.S. natural gas supply over the delivery system of imported fossil fuel, the high energy content of natural gas (about 30 kJ/m³ or 1000 Btu/ft³), and the clean-burning nature of natural gas (Kargbo et al., 2010). Figure 1 (Appendix) shows the locations of U.S. shale basins that bear natural gas. Due to the vast natural gas resources in formations such as the Marcellus Shale and Utica Shale, technically recoverable natural gas from U.S. shales is more than 1,744 trillion cubic feet (Kargbo et al., 2010). The Marcellus Shale formation alone—

which extends across the states of New York, Pennsylvania, Ohio, Maryland, and West Virginia—holds between 128 and 516 trillion cubic feet of natural gas (Pennsylvania, 2012). Relying on production techniques such as directional drilling and hydraulic fracturing, increasing unconventional oil and gas production can have the potential for economic growth and environmental benefits (Kargbo et al., 2010; Dale et al., 2013). However, research on these production techniques and the gas-producing, geologic formations of interest is important for developing safer production practices and addressing public health concerns (Soeder et al., 2014).

Hydraulic fracturing, a.k.a. “fracking”, is an unconventional oil and gas production technique that produces fractures in the rock formation that stimulate the flow of natural gas or oil, increasing the volumes that can be recovered (EPA & OEAAEE, 2015). Fractures are created by pumping large quantities of fluids at high pressure down a wellbore and into the target rock formation (EPA & OEAAEE, 2015). These fracking fluids commonly consist of water, chemical additives that open and enlarge fractures within the rock formation, and a proppant that holds the fractures open (GWPC, 2016). The additives may include varying percentages of the following: acid, breaker, bactericide, clay stabilizer, corrosion inhibitor, friction reducer, gelling agent, scale inhibitor, and surfactant (NYSDEC, 2011). The proppants (i.e. sand, ceramic pellets, or other small incompressible particles) hold open the newly created fractures (EPA & OEAAEE, 2015). Once the injection process is complete, the internal pressure of the rock formation causes fluid to return to the surface through the wellbore (EPA & OEAAEE, 2015).

Injected hydraulic fracturing fluids that return to the surface within the first two weeks after stimulation by fracturing are collectively called the “flowback” water (Haluszczak et al., 2013). Fracking fluids that flow from the well after the initial two-week period are “produced” waters (Haluszczak et al., 2013). Typically, ten to fifty percent of the injected fluid is returned to the surface via well casing (USEPA, 2012; Vidic et al., 2013). Flowback water contains the original or degraded additives as well as constituents mobilized from the formation (Wang et al., 2015). These can include a number of metals, metalloids, dissolved organics, and hydrocarbons (Gregory et al., 2011). Table 1 (Appendix) shows a typical range of concentrations for common constituents in flowback and produced waters from natural gas development in the Marcellus Shale (Gregory et al., 2011). Naturally occurring salts, radionuclides, and other elements will also appear in flowback water, which is suspected to occur because of subsurface mixing between the injected fracking fluid and salty waters or brines present in the formation (Abualfaraj et al., 2014). Barium and radium have been found to strongly correlate with total dissolved solids (TDS) (Renock et al., 2016). Barium concentrations and radium activities in produced waters have been shown to increase days after pumping has started, exceeding levels of 1,400 mg/L Ba and 5,000 to 16,000 pCi/L Ra (Chapman et al., 2012; Warner et al., 2012). These same waters can contain TDS exceeding 150,000 mg/L (Gregory et al., 2011) compared to a concentration of 35,000 mg/L TDS in seawater.

In addition to formation brines, solid-water interactions can also mobilize elements through a variety of pathways that depend on the formation composition and fracturing fluid chemistry (Wang et al., 2015). For example, the dissolution of acid-soluble minerals may be a release pathway since strong acids, such as hydrochloric or muriatic acid are used to initiate fractures, and they tend to be the single largest liquid additive in fracturing fluids (Gregory et al., 2011). Desorption of metals from host minerals can occur due to changes in pH and through the introduction of complexing agents (Wang et al., 2015). A complexing agent is a compound in

which independently existing molecules or ions of a nonmetal form coordinate bonds with a metal atom or ion. For iron control, EDTA and citrate form strong complexes with several metals and metalloids such as Pb (II), Cu (II), and Co (II), which can increase their mobility (Wang et al., 2015). Dissolved oxygen and other oxidative breakers, such as ammonium persulfate and magnesium peroxide are used to degrade the gel polymer chains by oxidative mechanisms (Fink, 2013; Vidic et al., 2013). These mechanisms may drive significant redox-sensitive geochemical reactions, e.g. increasing the solubility of reduced forms of uranium and chromium through oxidation (Wang et al., 2015).

Shale gas is natural gas produced from shale formations that typically function as both the low-permeable reservoir and the source rocks for the natural gas (Speight, 2013). Shale gas is distinct from gas in other reservoirs and from conventional gas. Figure 2 (Appendix) shows different types of onshore natural gas reserves (Gregory et al., 2011). The Middle Devonian Marcellus Shale formation is an organic-rich black shale formed from tectonic loading and sediments deposited in the oxygen-deficient sea of the Appalachian Basin (Lavergren et al., 2009; Curtis & Klemow, 2011). Black shales like the Marcellus Shale are known to be rich in sulfides and many potentially toxic elements, such as, Cd, Mo, U, Cr, Se, and V (Lavergren et al., 2009; Curtis & Klemow, 2011), and they are dominated by clay minerals (e.g. illite with some chlorite and smectite-illite mixed clays) with lesser quartz, silt, calcite, and pyrite (Roen, 1984; Engle and Rowan, 2014). Blauch et al. (2009) reported halite in Marcellus Shale cores within the bulk matrix and along the bedding planes. The Ordovician Utica Shale is a black shale as well, but with a high content of carbonates within the rock. The Marcellus Shale overlies the lower Devonian Onandaga Limestone and is overlain by sandstones, silts, and shales of the Hamilton Group and Mahantango Formation (Figure 3, Appendix). The section continues upward into the Upper Devonian and Lower Mississippian shales and conventional hydrocarbon-bearing sandstones where oil and gas in these units is thought to be sourced from the underlying Marcellus Shale (Carter, 2007). The units underlying the Marcellus Shale include the hydrocarbon-bearing Ordovician Utica Shale (Figure 3, Appendix) as well as the Silurian Salina Series evaporates, which transition to limestones, shales, and sandstones in the southwestern part of the play (Patchen & Carter, 2015).

Appalachian basinal brines are thought to permeate the Marcellus Shale and adjacent rock units. These brines are thought to be derived from residual Paleozoic seawater expelled from the Salina Series based on observed chloride and bromide relationships (Osborn & McIntosh, 2010). Heterogeneities in brine geochemistry in the Appalachian Basin suggest varying stages of alteration due to water-rock interactions, e.g. rock dissolution, sulfate reduction, and brine-aquifer rock interactions (Dresel & Rose, 2010; Osborn & McIntosh, 2010). As previously shown in paragraph three, brines in permeable host formations from Ordovician to Devonian eras can contain up to thousands ppm barium, which can possibly be explained by the sulfate-deficient brines reacting with Ba-containing minerals in the rock, e.g. silicates and carbonates (Dresel & Rose, 2010). Produced water from the Marcellus Shale is a Na-Ca-Cl brine with high levels of Sr, Ba, Br, and relatively high activities of ^{226}Ra and ^{228}Ra (Haluszczak et al., 2013; Engle & Rowan, 2014). Interestingly, Renock et al. (2016) suggests brine migration in the low-permeable black shale matrix to occur through horizontal and vertical fractures within the unit where brines can act as adsorbed water films on clays, capillary water, or free-flowing brine. Figure 4 (Appendix) shows the possible mechanisms contributing to the generation of produced water alkaline-earth (e.g. Ba, Ra, Sr) cation composition (Renock et al., 2016). This postulation

adds to the generally accepted hypothesis of subsurface mixing with deep formation brines as the source of high flowback TDS.

Studies have evaluated flowback chemistry and water-rock interactions between hydraulic fracturing fluids and corresponding shale formations. Dresel & Rose (2010) and Rowan et al. (2011) proposed there may be an alternative origin of high salinity in flowback water due to the release of *in situ* brines or formation water that they found from oil and gas wells in Pennsylvania. These saline brines in the Marcellus Shale formation are affecting the water quality of shallow drinking-water aquifers. However, the lack of a geological relationship to shale-gas wells shows that brine migration is occurring along natural pathways (Warner et al., 2012). Brines within shale formation likely contribute to the high Ra and TDS concentrations observed after well formation (Haluszczak et al., 2013). Chapman et al. (2012) suggested the modification of formation brines by radiogenic clays in the Marcellus Shale is required to explain Sr isotopic composition in flowback water. Studies have been conducted to mobilize metals and characterize metal association within specific solid phases as well as understand their origins in flowback fluid (Lavergren et al., 2009; Phan et al., 2015; Stewart et al., 2015; Wang et al., 2015). These studies used sequential extractions to characterize shale formation samples. Within the cation-exchangeable sites in the Marcellus Shale, nine to seventy-four percent of the total Ba was reported by Phan et al. (2015) and agreed upon by Stewart et al. (2015), although exchangeable Ba varies widely, and Ba availability and susceptibility to leaching is highly variable from different geographic locations and depths with the same well.

Many studies have researched hydraulic fracturing flowback brine, but there are limited published data focused on metals released from Marcellus Shale and Utica Shale drill cores. Some studies mentioned in the previous paragraph study outcrop samples rather than drill core samples in this research due to the difficulty in obtaining these materials. Drill cores are particularly important to study because they are collected from the deep “pay zone” where the hydraulic fracturing will occur. Also, there is little-to-no data on Utica Shale core samples and produced waters. The main objective of this research is to understand the intra- and inter-geologic unit metal composition of and contaminant release from Marcellus Shale and Utica Shale. Marcellus Shale and Utica Shale samples should experience similar elemental mobilization since they are thought to receive migrated formation brines from the same rock formation, the Salina Group. Rock dissolution and mixing with hydraulic fracking fluids may play a larger role in high elemental mobilization than formation brines. Interestingly enough, Utica Shale samples experienced more elemental mobilization than Marcellus Shale samples in anions and cations such as Br, Cl, and Na.

Materials and methods

1. Sample description

Rock samples were obtained from deep cores drilled in Ohio and northwestern Pennsylvania from the Pennsylvania Topographic and Geologic Survey. Table 2 (Appendix) enumerates all core samples used in the sequential extractions. Marcellus Shale and Utica Shale samples, along with their overlying and underlying confining units, were collected from multiple cores at multiple depths. Notable surrounding formations, i.e. Salina Series and Precambrian, were collected as well.

2. Methods

2.1. Sample preparation

Sequential extractions were carried out in acid-washed Teflon and HDPE centrifuge tubes, using ultrapure reagents to extract metals and radionuclides from Marcellus Shale and Utica Shale samples as well as samples from surrounding formations. Samples used in the sequential extractions were prepared by crushing, and then they were pulverized in a SPEX ball mill, ground with a mortar and pestle (if necessary) and sieved to finer than 150 μm . Some samples were oven dried at 100 °C and 0.5 g of each sample was distributed into labelled Teflon centrifuge tubes. Acid-washed, polypropylene centrifuge tubes were labelled and weight as well to be used as appropriate extractant tubes after each fraction.

2.2. Sequential extractions

Samples were characterized by sequential extractions through four different operationally-defined fractions: (1) water soluble minerals, (2) exchangeable sites on clays, (3) carbonate minerals, and (4) reducible species. The extractant solutions for these four steps were: (1) MQW/ultrapure water, (2) 1 N ammonium acetate buffered to pH 8, (3) 8% acetic acid, and (4) 0.5 N hydroxylamine hydrochloride in 25% acetic acid. Each extractant solution was N₂ purged to mimic anoxic conditions. Using a 1:15 rock mass:fluid volume ratio for every extraction, samples were shaken twice for about three hours on a rotary mixer, then centrifuged at 4500 rcf for four to ten minutes after each shake. The supernatant was decanted into labelled extractant tubes. Samples were rinsed three times with 5 mL N₂-purged ultrapure water to rid the previous extractant and centrifuged on the same settings. The supernatant was decanted into labelled extractant tubes. All supernatants from the same extraction were combined into the same labelled centrifuge tubes for each different sample. These extractants were syringe-filtered with a 0.45 μm membrane if necessary. After analyzing the anions, extractants were acidified with a few drops of 20% nitric acid for analysis of cations. Figure 5 (Appendix) summarizes these extraction processes. The soil pellet was used in the next extractant solution, and this rinsing-extraction procedure was conducted sequentially using the four extraction solutions. Two separate sets of sequential extractions were conducted. However, only anion data from the first fraction of the second sequential extraction has been recorded.

2.3. Analytical techniques

Extractant solutions from the sequential extractions were analyzed for anions by ion chromatography (IC) and cations by inductively coupled plasma mass spectrometry (ICP-MS). The first set of extractant solutions from the water soluble fraction were analyzed for their conductivities by a SevenExcellence conductivity meter. The second set of extractant solutions from the water soluble fraction were analyzed for their conductivities and redox.

Results and discussion

The cation and anion concentrations of different elements mobilized by the sequential extractions is shown in Table 3 and Table 4 (Appendix). The elements mobilized vary tremendously on their geochemical affinities and the fractions extracted by the different solutions. Of the cation concentrations, water-soluble, chloride-complexing cations, such as sodium are preferentially

released by ultrapure water. A range of 52% to 98% of the Na leached came from the water-soluble extraction. Calcium was only recorded in the water-soluble fraction.

Of the alkaline earth metals, such as strontium and barium, there was variation in their mobilization due to the sequential extractions. Figure 6 (Appendix) shows the fraction of Na, Ba, and Sr extracted from each leaching solution relative to the total amount extracted by all four leaches combined. Sr is extracted in either the exchangeable sites on clays (up to 81%) or carbonate minerals (up to 83%). Notably, Ba, which is highly concentrated in water produced from Marcellus Shale natural gas wells, is held mainly in the exchangeable sites on clays (73% to 91%) for most of the samples. One sample from the Salina Group and Middle Ordovician formations each had barium extracted from either both the exchangeable sites and carbonates fractions (MO6) or mainly the carbonate fraction (SG1). Although X-ray diffraction was not done on any of the rock samples, this trend may be because these samples do not have high clay content. The Salina Group sample may contain mainly evaporate while the Middle Ordovician sample was from the Black River Limestone, most likely containing mainly calcium carbonate. Excluding those samples, this suggests that Ba has a strong affinity for charged surfaces on clay minerals. Barite (BaSO_4) should not dissolve by the leaching solutions used in this study, which is consistent with its known dissolution behavior (Paytan et al., 1993).

Bromide, chloride, and sulfate were analyzed in the ultrapure water leaches only. Cl is present at levels roughly equivalent to Na (mass Na/Cl ratio average of all samples: 0.7; Marcellus Shale samples: 1.2; Utica Shale samples: 0.7). The high sulfate concentrations leached from the rock samples may have made it more difficult to leach Ba. The sulfate mass content in all rock samples averaged to about 2444 $\mu\text{g SO}_4/\text{g sample}$ (33.7 mg/L). The high sulfate leached from the rock samples may have been due to precipitation in the extractant centrifuge tubes while waiting in the refrigerator before analysis as well as the sequential extraction conditions not being anoxic enough. It may be better to complete these extractions in a glovebox and acidify samples as soon as possible to eliminate most pathways for sulfate to form. Under reducing, deep subsurface conditions, it may be possible to extract greater quantities of soluble and exchangeable Ba from the rock as long as sulfate levels remain low (i.e. by bacterial sulfate reduction), suppressing barite precipitation (Stewart et al., 2015).

Sodium, barium, bromide, and chloride released from the Marcellus Shale and Utica Shale samples are shown in Figure 7 (Appendix). Utica Shale samples released higher concentrations of Na, Br, and Cl than Marcellus Shale samples. Marcellus Shale sample, MS3, released an overwhelming amount of Ba (556 $\mu\text{g/g sample}$) compared to the other samples. This sample was the only Marcellus Shale sample from Pennsylvania while the other Marcellus sample was from Ohio along with the Utica samples.

The conductivities of rock samples were analyzed and plotted in Figure 8 (Appendix). The average conductivity among rock samples was 0.3 mS/cm, the highest being 2.7 mS/cm from a Salina Group rock sample (SG2). The average redox among rock samples was 176.1 mV, the highest being 244.2 mV from the Precambrian rock sample (P1). The Utica Shale samples averaged higher conductivities and redox than the Marcellus Shale samples.

It is possible Na, Br, and Cl may be leached from rock dissolution. Dilution and mixing of original formation brines with injected fracking fluid can be expressed in Figure 9 (Appendix). Researchers including Dresel and Rose (2010), Haluszczak et al. (2013), and Ziemkiewicz et al. (2015) use a Cl/Br plot to show the connection between conventional gas well brines and

seawater evaporation. The evaporation of seawater leads to increased Cl and Br during the initial evaporation and precipitation of calcite and gypsum. However, once halite precipitates out, the halite contains much lower Br than the associated brine (Haluszczak et al., 2013). This halite precipitation leads to a nearly horizontal path for the residual brine on the plot in Figure 9 (Appendix). Due to this effect, brines with high Br/Cl result from evaporation of seawater past the point of halite precipitation, and injected fracking fluid may then mix with these highly evaporated brines to produce brines plotting at Br values higher than that of seawater (Haluszczak et al., 2013). Figure 9 (Appendix) shows the Cl/Br ratio of produced water lies fairly below the seawater evaporation path, indicating dilution of original brine with injected fracking fluid. Produced water plots to the high-Br side of the seawater evaporation path, indicating that halite dissolution is not the major source of Cl in produced waters. If it were, produced waters would yield values with extremely high Cl/Br ratios (Haluszczak et al., 2013). In addition to the produced water data plotted against the seawater evaporation path, rock extraction data is also plotted, indicating a similar path as the produced water data. This trend shows that high brine in produced waters can instead result from injected fracking fluids dissolving salts from the rock formations.

Sodium and chloride released from the rock formations can be expressed in Figure 10 (Appendix). TDS in produced waters is not primarily due to simple congruent dissolution of halite. Congruent dissolution is the total dissolution of salt via basinal brines. It forms subsurface Na-Cl brines with high Cl contents and higher Br/Cl ratios compared to non-evaporite subsurface waters (Worden, 1996). Deviation from the 1:1 ratio line in Figure 10 (Appendix) indicates that either Na or Cl is sourced from rock dissolution of salts rather than formation brines. Most of the rock extracts fall below the 1:1 ratio line, indicating that more Cl is leached from the rock formation. The Utica Shale extracts leached slightly more Cl from the rock samples. However, Marcellus Shale extracts leached slightly more Na from the rock samples.

One of the major concerns for flowback and produced water is TDS removal. Analogously, Na, Cl, and Br were among the highest contaminants leached from the Marcellus Shale and Utica Shale samples. Fortunately, industrial-grade wastewater treatment facilities are able to handle high TDS in shale produced waters, and their usage rate has remained fairly constant (Rodriguez and Soeder, 2015). Treated water from industrial facilities can be reused or discharged into surface waters. In Pennsylvania, the total rate of recycling increased from 13% to 72% as of 2011 (Rodriguez and Soeder, 2015).

Other wastewater treatment options, like deep underground injection, are ruled out frequently. Marcellus Shale gas development occurs in many areas where insufficient disposal wells are available, and the construction of new disposal wells is complex, time-consuming, and costly (Abualfaraj et al., 2014). Discharge and dilution of flowback and produced water into publicly owned municipal wastewater treatment plants (POTWs) has been utilized. However, the amount of TDS in these waters that can be accepted is limited (Gregory et al., 2011). For example, in Pennsylvania, the amount of oil and gas wastewater must not exceed one percent of the average daily volume of waste handled by the POTW (Gregory et al., 2011). Chemical precipitation processes, such as coagulation and flocculation, can be used to remove suspended solids and inorganic-scale-forming compounds, but are not effective for removing dissolved solids (Abualfaraj et al., 2014). A study of shale gas wastewater effluent from publicly owned treatment facilities found that even after treatment through filtration or flocculation, certain inorganic solids remained at unacceptable mean and maximum concentrations when compared

with various drinking water standards (Ferrar et al., 2013). While organic compounds may have been removed to acceptable levels, inorganics, such as magnesium, chloride, and TDS, were not reduced to drinking water MCLs after undergoing various physical treatment processes for 8–12 hours of residence time (Ferrar et al., 2013). Bromide concentrations in TDS can be concerning as well. While Br is not harmful as a diluted salt, it reacts with chlorine during the water treatment process to create trihalomethane, a known carcinogen (Rodriguez and Soeder, 2015).

Conclusions

There are two main proposed reaction mechanisms for mobilizing salts and metals in the Marcellus Shale, Utica Shale, and surrounding formations: (1) injected fracking fluids mixing with historic and migrated formation brines and salts, and, (2) injected fracking fluids mixing with the rock formation to dissolve associated salts and metals.

The main conclusions of this research are:

1. Multiple reaction mechanisms release and leach salts and metals from the target rock formation, e.g. dilution and mixing of formation brines (Dresel and Rose, 2010), rock dissolution of salts, dolomitization (Haluszczak et al., 2013), sulfate reduction (Haluszczak et al., 2013), and induced micro-fractures in rock (Renock et al., 2016).
2. Elements such as Na, Br, and Cl can be leached from rock dissolution of salts as indicated by graphical relationships and trends.
3. Utica Shale produced waters have the potential to be saltier and contain higher concentrations of elements such as Br and Cl than Marcellus Shale produced waters. Na, Br, and Cl leached from Utica Shale samples is higher than those leached from Marcellus Shale samples.

The characterization of more Pennsylvanian drill cores of Marcellus Shale and Utica Shale is needed. The analysis of these cores would aid in finding out more information on Utica Shale elemental release as well as explain the spike in barium extracted from the one Pennsylvanian Marcellus Shale sample (MS3).

Appendix

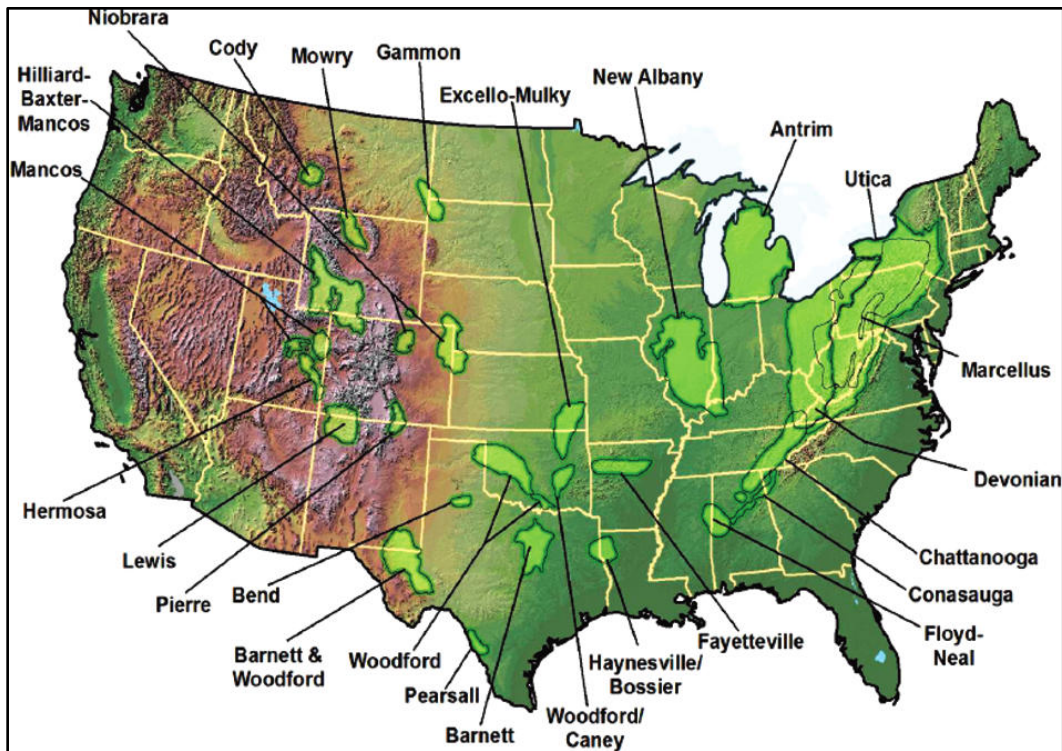


Figure 1: The locations of shale basins across the U.S. (Kargbo et al., 2010).

Constituent	Low (mg/L)	Medium (mg/L)	High (mg/L)
Total dissolved solids	66,000	150,000	261,000
Total suspended solids	27	380	3200
Hardness (as CaCO ₃)	9100	29,000	55,000
Alkalinity (as CaCO ₃)	200	200	1100
Chloride	32,000	76,000	148,000
Sulfate	No Data	7	500
Sodium	18,000	33,000	44,000
Calcium, total	3000	9800	31,000
Strontium, total	1400	2100	6800
Barium, total	2300	3300	4700
Bromide	720	1200	1600
Iron, total	25	48	55
Manganese, total	3	7	7
Oil and grease	10	18	260
Total radioactivity	No Data	No Data	No Data

Table 1: Typical range of common constituents in flowback water from natural gas development in the Marcellus shale formation (Gregory et al., 2011).

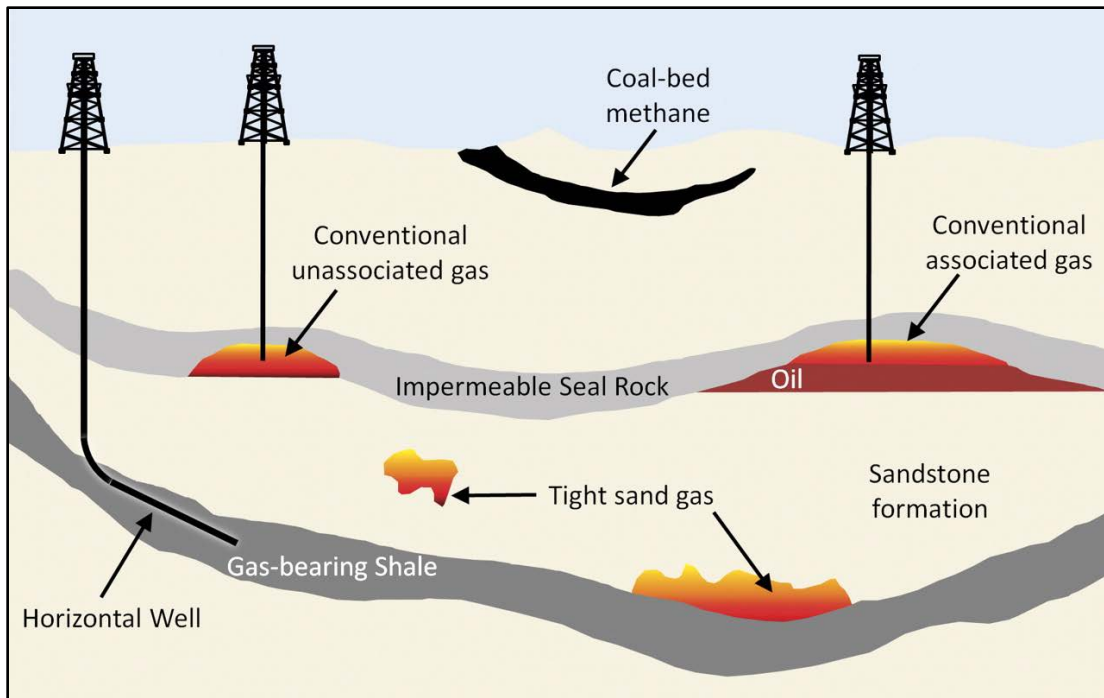


Figure 2: The types and common orientations of onshore natural gas resources (Gregory et al., 2011).

359 MYA	Devonian	Ohio Shale	Key
		Genesee/Sonyea/West Falls/Java Fms	
		Tully Limestone	
		Hamilton Grp/Mahantango Sandstone	
		Marcellus Shale Formation	
		Onondaga Limestone	
		Bois Blanc Fm/Huntersville Chert	
		Ridgeley Sandstone	
		Helderberg Group	
		416 MYA	
	Salina Group		
	Lockport Dolomite/McKenzie Fm		
	Clinton Group		
443 MYA	Ordovician	Medina Grp/Tuscarora Fm	Cap rocks Pay zone Basement
		Queenston Shale	
		Reedsville Shale	
		Utica Shale Formation	
		Trenton/Black River/Point Pleasant Fms	
		Loysburg	
448 MYA		Beekmantown Group	

Figure 3: The generalized stratigraphic nomenclature representing Devonian, Silurian, and Ordovician rocks. The key highlights which formations overlie (cap rock) and underlie (basement) the Marcellus Shale and Utica Shale formations (pay zone). The key also highlights the suggested source of brines in the Marcellus Shale.

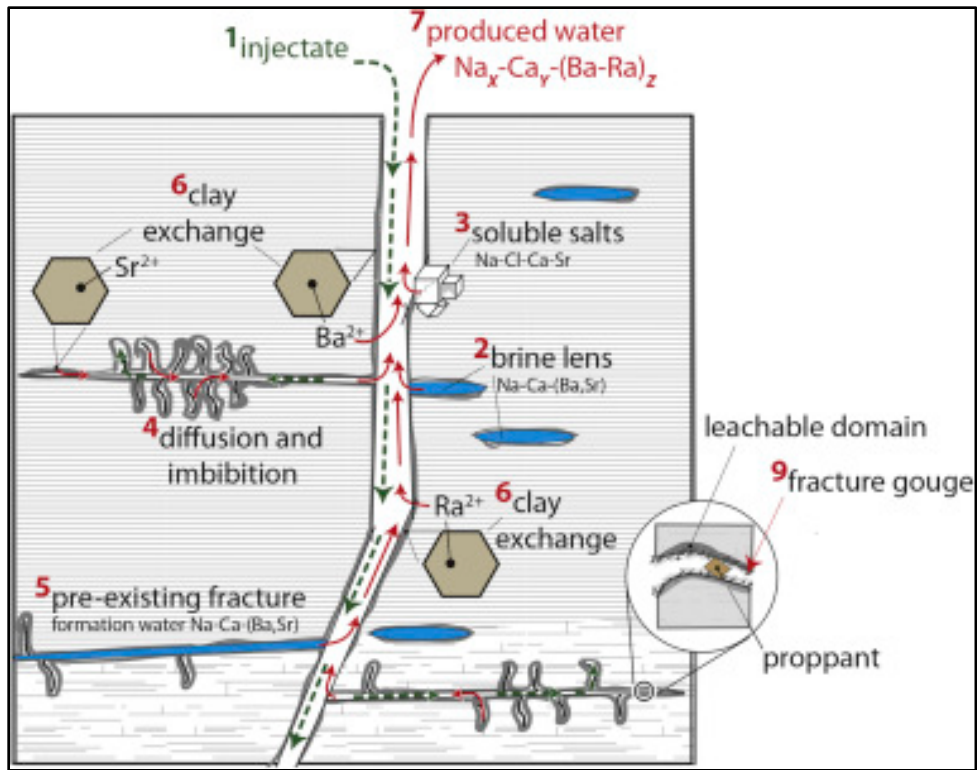


Figure 4: The possible mechanisms contributing to the generation of produced water alkaline-earth (i.e. Ca, Sr, Ba, Ra) cation composition (Renock et al., 2016).

Sample ID	Formation	Age	Depth (ft)	Location	GPS	Core #	Core ID
M 1	Big Lime	M	4148	Ohio	39.7137 -81.4619	2936	4
M 2	Berea Sandstone	M	808	Ohio	40.7710 -81.4098	991	6
SG 1	Salina Group	UD	1645	Ohio	38.5943 -82.8220	3409	2
UD 1	Kope Formation	UD	943	Ohio	40.5873 -83.2407	3372	3
UD 2	Angola Shale	UD	3618	Ohio	39.7137 -81.4619	2936	4
UD 3	Rhinestreet Shale Mahantango	UD	3838	Ohio	39.7137 -81.4619	2936	4
MD 1	Sandstone	MD	5108	PA	41.8688 -78.6124	EGSP #1	
MS 1	Marcellus Shale	MD	4131	Ohio	39.7137 -81.4619	2936	4
MS 2	Marcellus Shale	MD	4135	Ohio	39.7137 -81.4619	2936	4

MS 3	Marcellus Shale	MD	5162.5	PA	41.8688	EGSP		
	Onondaga				-78.6124	#1		
MD 2	Limestone	MD	4138	Ohio	39.7137		2936	4
	Onondaga				41.8688	EGSP		
MD 3	Limestone	MD	5211.3	PA	-78.6124	#1		
					40.7710			
SG 2	Salina Group	S	3557	Ohio	-81.4098		991	6
					40.5873			
UO 1	Queenston	UO	672	Ohio	-83.2407		3372	3
					40.5873			
UO 2	Queenston	UO	428	Ohio	-83.2407		3372	3
					39.5659			
US 1	Utica Shale	MO	839	Ohio	-84.1160		2627	1
					39.5659			
US 2	Utica Shale	MO	849	Ohio	-84.1160		2627	1
					39.5659			
US 3	Utica Shale	MO	859	Ohio	-84.1160		2627	1
					39.5659			
US 4	Utica Shale	MO	893	Ohio	-84.1160		2627	1
					40.5873			
US 5	Utica Shale	MO	1144	Ohio	-83.2407		3372	3
					39.5659			
MO 1	Point Pleasant	MO	819	Ohio	-84.1160		2627	1
					39.5659			
MO 2	Point Pleasant	MO	829	Ohio	-84.1160		2627	1
					40.5873			
MO 3	Point Pleasant	MO	1344	Ohio	-83.2407		3372	3
					39.5659			
MO 4	Trenton	MO	927	Ohio	-84.1160		2627	1
	Black River				39.5659			
MO 5	Limestone	MO	1090	Ohio	-84.1160		2627	1
	Black River				40.5873			
MO 6	Limestone	MO	1546	Ohio	-83.2407		3372	3
					39.5659			
P 1	Precambrian	P	3458	Ohio	-84.1160		2627	1

Table 2: A list of all core samples and their corresponding formation names, depths, and locations used in the sequential extractions. Organized by geologic period. SG: Salina Group. UD: Upper Devonian. MD: Middle Devonian. MS: Marcellus Shale. UO: Upper Devonian. US: Utica Shale. MO: Middle Ordovician. P: Precambrian.

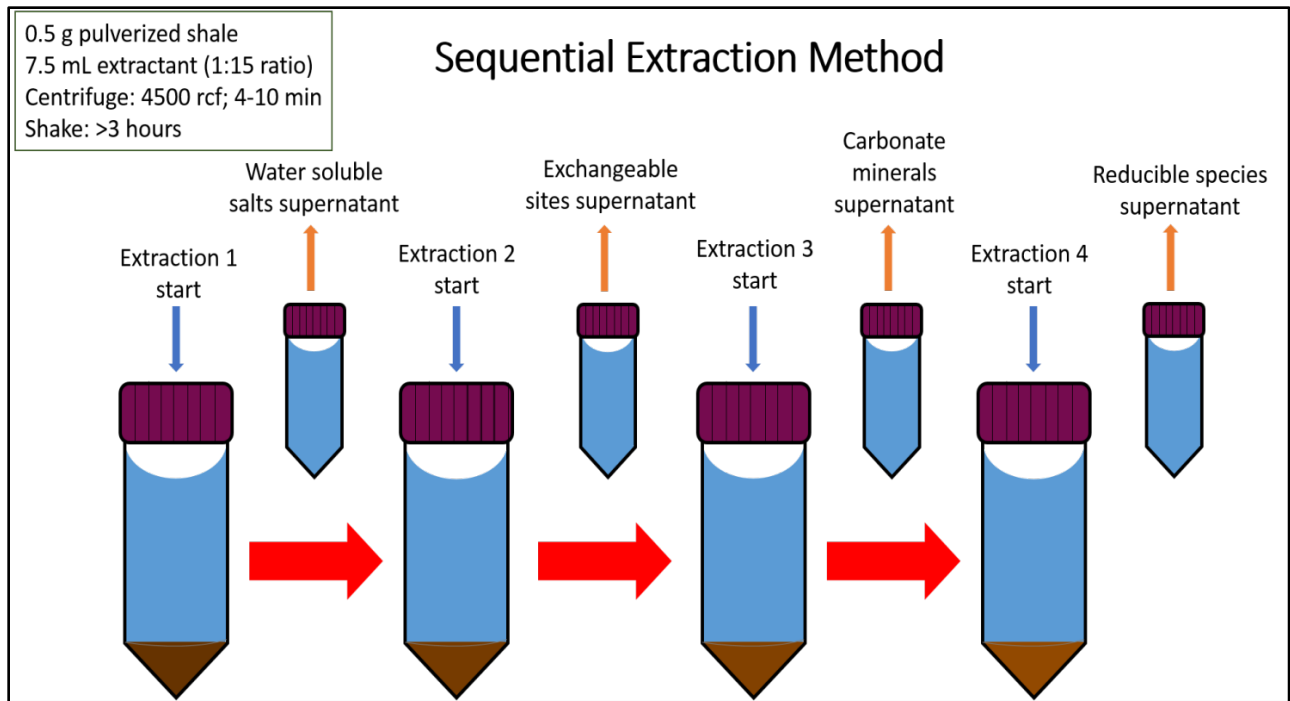


Figure 5 Legend

Extraction 1	N ₂ purged MQW
Extraction 2	N ₂ purged 1 N ammonium acetate buffered to pH 8
Extraction 3	N ₂ purged 8% acetic acid
Extraction 4	N ₂ purged 0.5 N hydroxylamine hydrochloride in 25% acetic acid
Analysis on Extractions	IC: analyzes anions in water soluble fraction ICP-MS: analyzes cations in all fractions
Extraction 1 Only Analysis	Conductivity and redox measurements

Figure 5: This diagram and corresponding legend show a simplified version of the sequential extraction method.

Sample	Target Matrix	µg / g sample	Na	Al	Ca	Mn	Fe	Co	Sr	Ba	U	Depth (ft)
SG 1	Salts	124.44	1.11	184.71	0.02	-	0.12	4.46	-	0	1645	
	Exchange	20.85	5.66	-	0.34	-	0.04	7.24	0.34	0.02	-	
	Carbonates	55.86	30.94	-	33.41	264.20	0.05	20.85	23.46	0.27	-	
	Reducible	21.39	6.85	-	4.50	47.19	0.01	3.57	0.07	0.06	-	
	Σ	222.55	44.56	-	38.26	311.40	0.22	36.11	23.86	0.35		
UD 3	Salts	1077.83	18.47	144.15	0.10	-	-	4.64	0.05	0	3838	
	Exchange	43.00	3.74	-	40.36	0.12	0.07	30.12	15.02	0.03	-	
	Carbonates	10.24	179.98	-	74.22	587.57	0.53	1.80	0.41	0.02	-	
	Reducible	56.40	222.38	-	4.20	533.52	0.39	0.41	0.97	0.01	-	
	Σ	1187.47	424.56	-	118.89	1121.22	0.99	36.97	16.45	0.06		
MD 1	Salts	551.81	35.04	483.66	0.24	3.43	-	29.40	2.24	0.011	5108	
	Exchange	155.84	8.14	-	5.28	0.68	0.06	39.59	161.91	0.06	-	
	Carbonates	39.02	251.96	-	51.49	597.80	0.46	44.44	4.38	0.13	-	
	Reducible	41.68	181.42	-	2.25	526.94	0.51	1.51	10.92	0.02	-	
	Σ	788.35	476.56	-	59.26	1128.86	1.04	114.93	179.46	0.22		
MS 2	Salts	917.18	19.28	256.91	0.09	0.47	0.01	25.95	0.18	0.004	4131	
	Exchange	24.07	5.36	-	8.75	0.14	0.14	51.91	16.24	0.09	-	
	Carbonates	18.26	149.89	-	30.43	441.27	0.69	14.67	0.29	0.09	-	
	Reducible	13.25	125.70	-	1.90	463.21	1.48	1.06	1.76	0.02	-	
	Σ	972.76	300.22	-	41.18	905.09	2.33	93.59	18.46	0.21		
MS 3	Salts	690.95	13.71	988.54	0.55	8.33	0.03	47.79	8.76	0.749	5162.5	
	Exchange	24.71	4.36	-	4.28	-	0.10	49.25	475.21	0.96	-	
	Carbonates	6.50	69.10	-	4.02	129.89	0.31	2.53	16.17	0.17	-	
	Reducible	21.00	107.93	-	2.22	956.78	1.46	2.43	55.50	0.40	-	
	Σ	743.17	195.10	-	11.07	1095.01	1.91	102.01	555.64	2.28		
MD 2	Salts	773.15	19.13	257.06	0.13	0.36	-	27.57	0.06	0.003	4138	
	Exchange	20.35	5.98	-	8.19	0.36	0.10	44.12	9.12	0.06	-	
	Carbonates	47.22	150.39	-	78.49	736.19	0.48	48.10	1.45	0.19	-	
	Reducible	11.77	79.63	-	1.41	335.39	0.73	1.16	2.17	0.02	-	
	Σ	852.49	255.13	-	88.23	1072.31	1.31	120.95	12.80	0.27		
MD 3	Salts	116.88	20.98	367.88	0.18	2.27	0.002	13.52	0.07	0.037	5211.3	
	Exchange	14.55	4.51	-	0.64	-	0.08	15.25	2.61	0.28	-	
	Carbonates	20.63	13.97	-	11.22	67.54	0.07	27.21	0.32	0.25	-	
	Reducible	10.27	19.24	-	0.24	141.08	0.18	0.99	0.67	0.10	-	
	Σ	162.33	58.69	-	12.28	210.89	0.34	56.98	3.67	0.66		
UO 1	Salts	680.19	10.90	185.80	0.04	-	-	4.09	-	0.002	428	
	Exchange	9.59	2.07	-	4.75	0.11	0.07	12.15	2.59	0.05	-	
	Carbonates	23.87	141.44	-	100.72	467.81	0.66	21.74	0.30	0.06	-	

	Reducible	12.57	116.31	-	2.31	299.47	0.54	0.87	0.66	0.02	-
	Σ	726.21	270.71	-	107.81	767.38	1.28	38.85	3.55	0.13	
US 2	Salts	2468.57	20.36	329.30	0.61	2.91	0.11	18.24	0.34	0.003	849
	Exchange	25.86	2.45	-	11.49	0.10	0.09	55.23	12.24	0.04	-
	Carbonates	21.21	249.97	-	83.80	766.25	0.91	64.26	0.46	0.05	-
	Reducible	12.09	179.18	-	3.71	433.24	0.50	2.77	1.08	0.03	-
	Σ	2527.72	451.97	-	99.61	1202.50	1.61	140.50	14.12	0.13	
US 5	Salts	1608.96	5.86	598.12	0.80	-	-	14.34	0.23	0.010	1144
	Exchange	23.15	1.65	-	23.53	0.07	0.18	33.83	9.01	0.11	-
	Carbonates	20.89	119.27	-	54.92	466.16	0.81	10.98	0.28	0.12	-
	Reducible	12.93	140.07	-	7.63	810.49	1.25	1.78	0.91	0.07	-
	Σ	1665.94	266.85	-	86.88	1276.72	2.25	60.92	10.42	0.31	
MO 4	Salts	1482.42	22.25	325.99	0.06	-	-	13.49	0.15	0.003	927
	Exchange	32.51	4.87	-	5.55	0.15	0.05	57.52	13.98	0.04	-
	Carbonates	23.79	468.09	-	75.58	1039.14	0.86	64.65	0.64	0.06	-
	Reducible	23.25	395.53	-	5.49	724.53	0.64	4.05	2.53	0.05	-
	Σ	1561.97	890.74	-	86.67	1763.82	1.55	139.72	17.30	0.16	
MO 6	Salts	84.04	24.04	195.49	0.06	-	-	7.07	-	0.002	1546
	Exchange	18.06	7.51	-	0.52	0.04	0.11	23.17	0.90	0.02	-
	Carbonates	37.56	66.69	-	55.71	220.84	0.16	149.14	0.73	0.04	-
	Reducible	23.46	20.98	-	0.18	35.93	0.03	0.17	0.17	0.01	-
	Σ	163.11	119.22	-	56.46	256.81	0.30	179.55	1.80	0.07	

Table 3: Metal concentrations extracted from Marcellus Shale, Utica Shale, and corresponding surrounding formations for targeted fractions. Dash signifies below detection level. na: Not Analyzed. SG: Salina Group. UD: Upper Devonian. MD: Middle Devonian. MS: Marcellus Shale. UO: Upper Devonian. US: Utica Shale. MO: Middle Ordovician.

Sample	Conductivity (mS/cm)	Redox (mV)	Cl (ug/g)	Br (ug/g)	SO ₄ ⁻ (ug/g)	Depth (ft)
M 1	0.113	156.8	495.06	1.92	344.75	4148
M 2	0.134	213.2	1278.07	3.85	105.77	808
SG 1	0.125	113.60	437.62	25.2	103.72	1645
UD 1	0.203	165.3	1729.8	11.2	368.29	943
UD 2	0.195	159.6	1357.92	14.59	720.75	3618
UD 3	0.166	164.20	1765.02	36.93	524.28	3838
MD 1	0.176	nd	616.68	25.73	3643.94	5108
MS 1	0.205	164.5	736.02	6.18	1938.4	4135
MS 2	0.220	158.60	798.92	27.46	2068.98	4131
MS 3	0.289	nd	584.88	24.14	7888.18	5162.5
MD 2	0.129	nd	884.98	26.15	1551.72	4138
MD 3	0.091	nd	307.24	23.97	1214.67	5211.3
SG 2	2.716	203.8	6069.22	nd	86083.7	3557
UO 1	0.140	227.50	936.16	26.62	754.41	428
UO 2	0.677	211.3	3400.8	21.62	10281.6	672
US 1	0.346	171.4	2147.42	18.43	3548.28	839
US 2	0.343	164.40	3393.13	67.99	2837.07	849
US 3	0.344	157.8	2168.21	17.27	3241.4	859
US 4	0.313	172.6	2326.33	18.07	2258.79	893
US 5	0.470	178.00	2763.92	37.31	5388.73	1144
MO 1	0.247	187.3	2176.12	17.71	1117.10	819
MO 2	0.351	161.8	2466.14	17.68	2113.43	829
MO 3	0.210	159.1	1206.61	8.09	1351.07	1344
MO 4	0.232	nd	1944.09	35.25	3251.43	927
MO 5	0.076	163.8	231.05	0.38	185.81	1090
MO 6	0.061	nd	160.69	nd	101.78	1546
P 1	0.145	244.2	1727.09	12.39	81.47	3458

Table 4: Conductivities, redox, and anion concentrations extracted from Marcellus Shale, Utica Shale, and corresponding surrounding formations for targeted fractions. nd: No Data. SG: Salina Group. UD: Upper Devonian. MD: Middle Devonian. MS: Marcellus Shale. UO: Upper Devonian. US: Utica Shale. MO: Middle Ordovician.

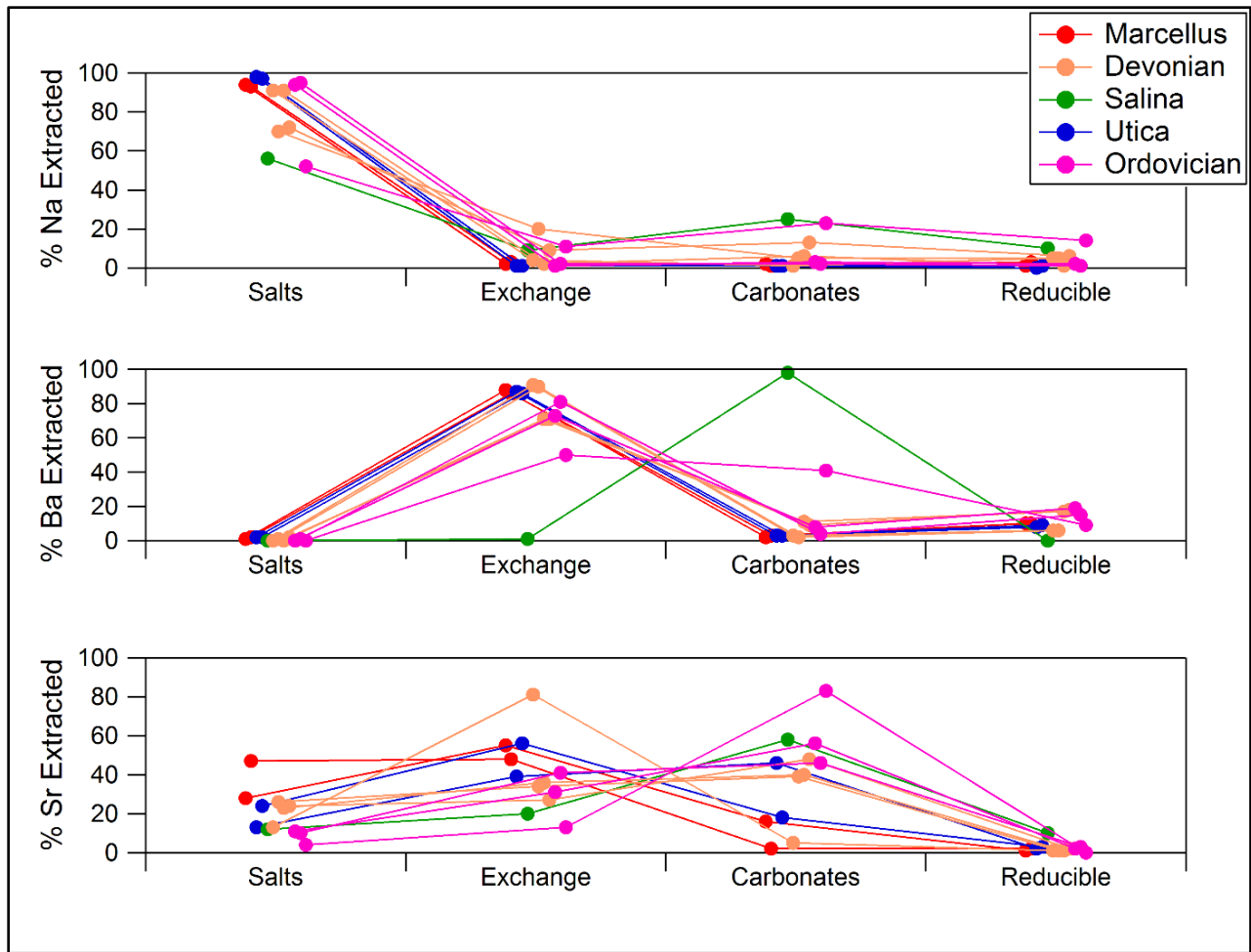


Figure 6: Na, Ba, and Sr extracted from each leaching fraction relative to the total amount extracted by all four leaches combined. Na is mainly leached from water-soluble salts. Ba is mainly leached from exchangeable sites on clays. Sr is mainly leached from both exchangeable sites and carbonates.

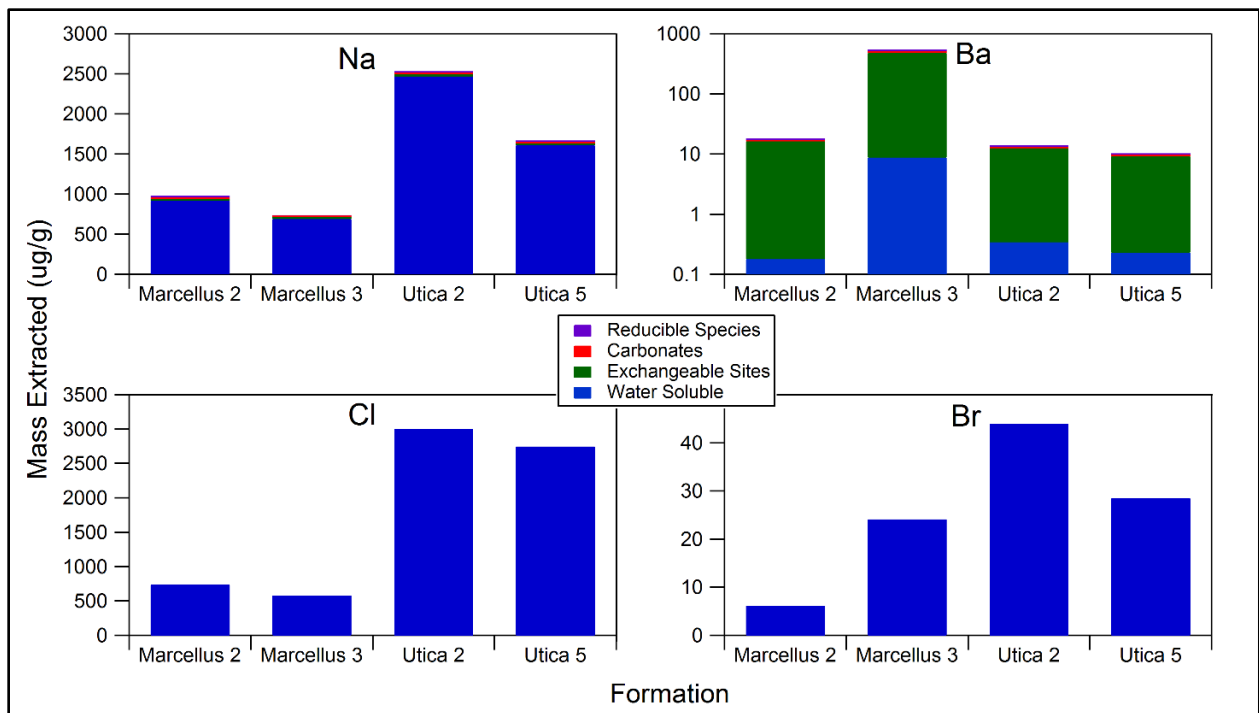


Figure 7: Mass content of Na, Ba, Cl, and Br released from sequential extractions. Na and Ba were analyzed in all four fractions. Cl and Br were analyzed in the water soluble fraction. Ba is plotted on a log scale to show lower values. Marcellus 2 and Marcellus 3 correspond to sample IDs MS2 and MS3. Utica 2 and Utica 5 correspond to sample IDs US2 and US5.

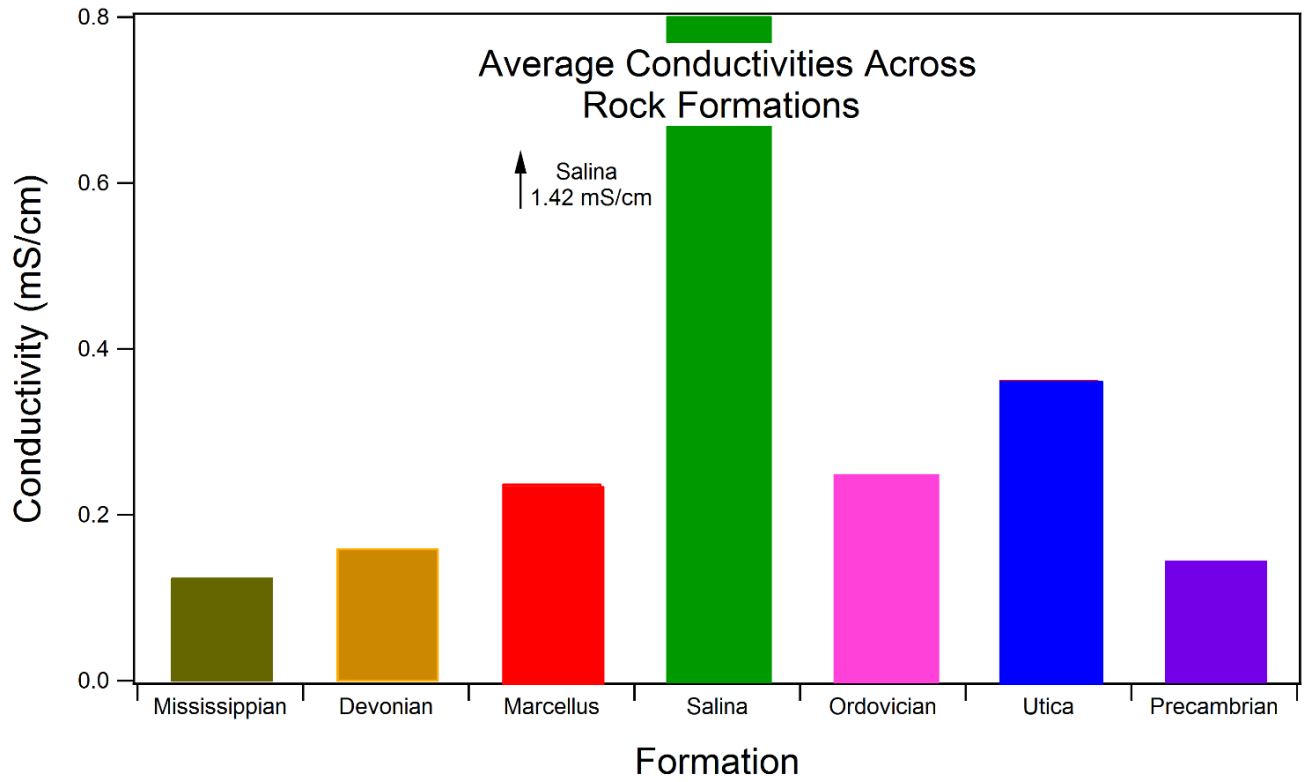


Figure 8: The average conductivities of the rock samples from the water-soluble fraction. The Salina Group samples (SG1 and SG2) had the highest average conductivity.

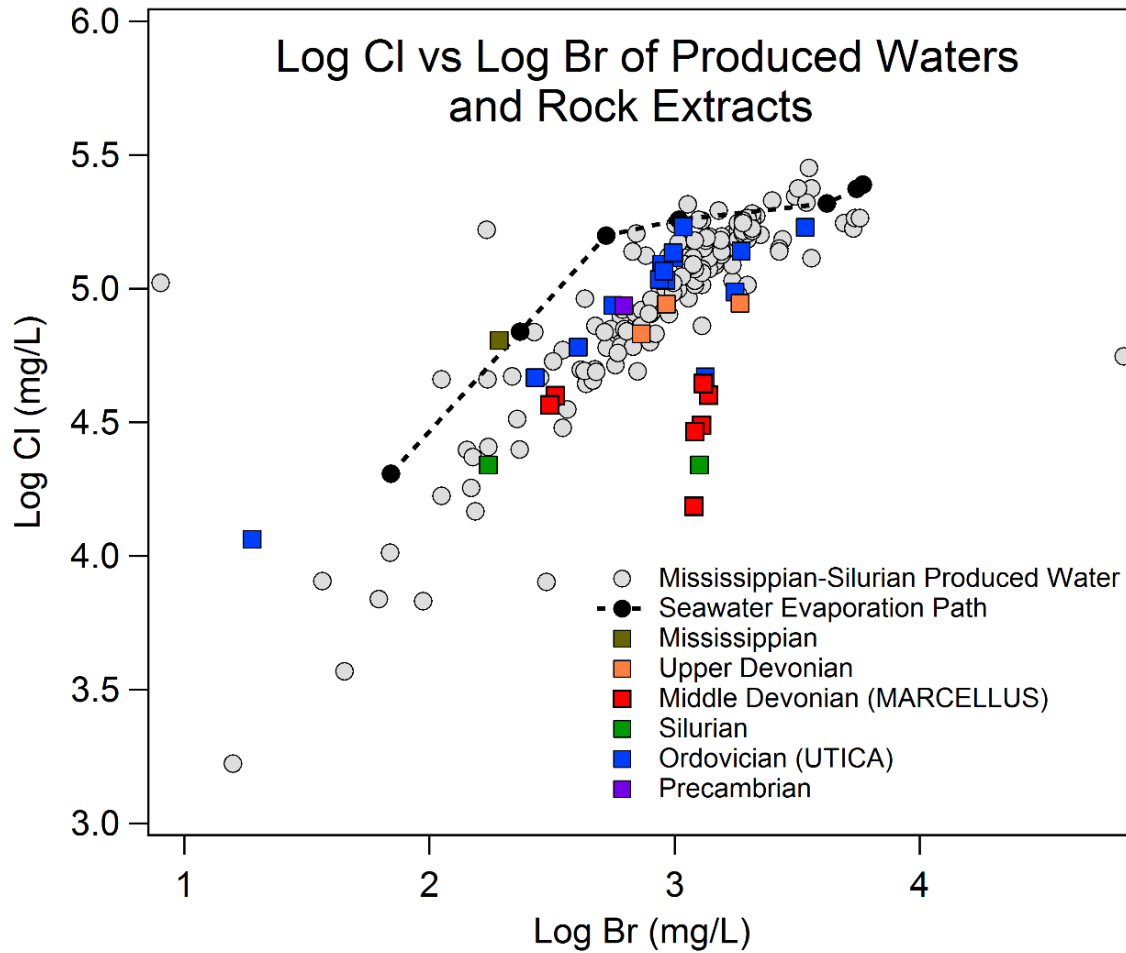


Figure 9: Plot of Log Cl vs Log Br, indicating the path of the evaporation of seawater (dashed line). Produced water data (grey dots) and rock extracts (colored squares) are plotted as well. Utica Shale rock samples follow the trend the best. Rock extracts are plotted as a 50:1 rock:fluid ratio.

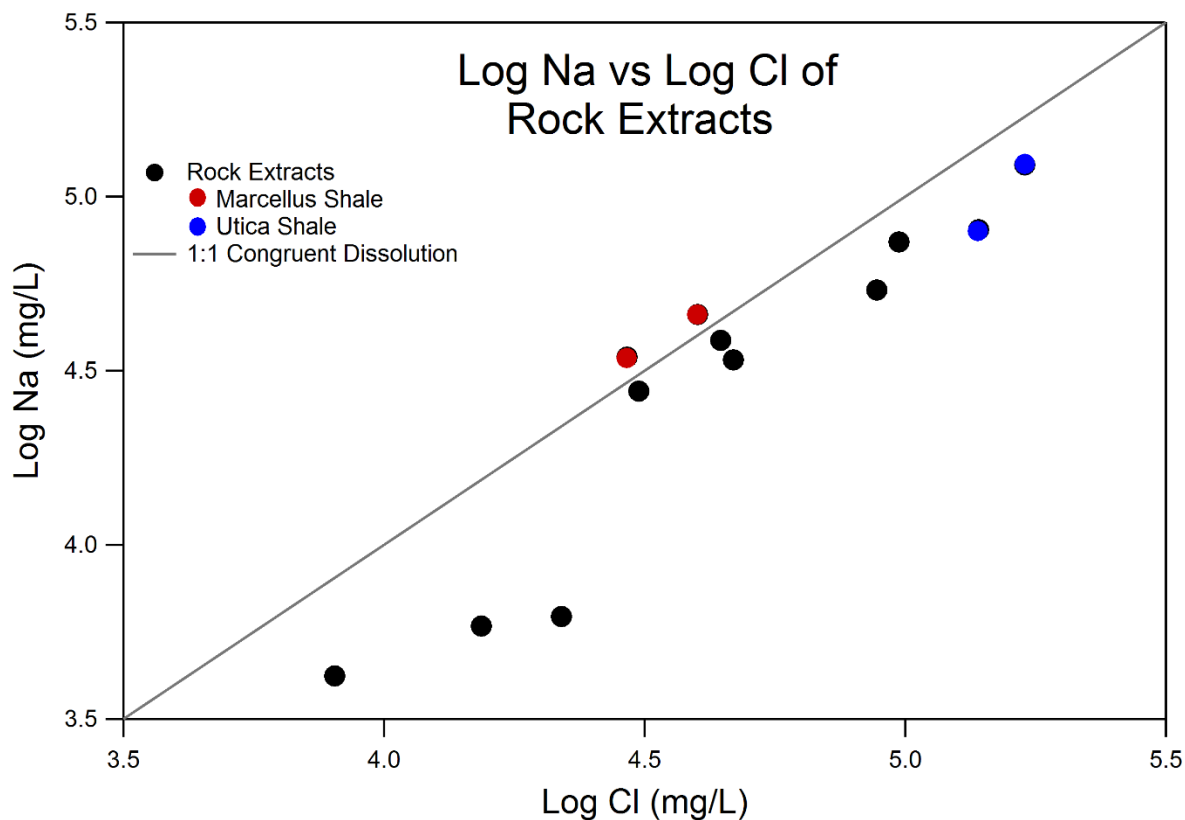


Figure 10: Plot of Log Na vs Log Cl, indicating the role rock dissolution plays in leaching these elements from the rock samples in the sequential extractions. Na may be leached from Marcellus Shale rock while Cl may be leached from Utica Shale rock. Deviation from the 1:1 line indicates that either Na or Cl is being sourced from a reaction mechanism different from historic formation brines. Rock extracts are plotted as a 50:1 rock:fluid ratio.

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Covariance and Quantum Cosmology

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Abstract

In relativity, time is relative between reference frames. However, quantum mechanics requires a specific time coordinate in order to write an evolution equation for wave functions. This difference between the two theories leads to the problem of time in quantum gravity. One method to study quantum relativity is to interpret the dynamics of a matter field as a clock. In order to test the relationship between different reference frames, an isotropic cosmological model with two matter ingredients is introduced. One is given by a scalar field and one by vacuum energy or a cosmological constant. There are two matter fields, and thus two different Hamiltonians are derived from the respective clock rates. Semi-classical solutions are found for these equations and a comparison is made of the physical predictions that they imply.

Introduction

Quantum mechanics and general relativity are two of the most rigorously tested theories in modern physics. Quantum mechanics, which excels at describing the smallest constituents of the universe, has the power to explain many of the problems that baffled classical physicists on the small and every day scale. General relativity on the other hand, is best at describing the universe on a large scale. The framework of general relativity models gravitation on the geometric properties of a continuous space-time that spans the universe. Furthermore, general relativity is the basis of many modern cosmological models. Problems arise when one tries to incorporate quantum mechanics with theories of gravitation or cosmology, typically referred to as quantum gravity or quantum cosmology. The problems stem from the mathematical differences underlying quantum mechanics and general relativity. While general relativity requires space to be continuous, quantum mechanics requires that everything is “quantized”, or to exist in small pieces. This fundamental difference may, on the surface, seem like something that can be dealt with easily. However, the problems that follow from this difference have challenged physicists for the past century.

This paper will deal with the theory of quantum cosmology. Quantum cosmology starts with a quantization of a structureless, homogeneous chunk of space as a first approximation to a “space-time” atom.

The Friedmann equations are a set of equations in physical cosmology that govern the expansion of space in homogeneous and isotropic models of the universe within the context of general

relativity. Classically, the Friedmann equation is covariant so one is able to transform the time parameters without changing other physical parameters. Quantization, however, introduces correction terms to the classical model that makes it unclear whether or not we can still transform time in this way [1]. The motivation for this paper is the fact that while the time coordinate is not quantized since it is a coordinate and not directly observable, we are still able to model time using a method called deparameterization. Deparameterization involves using matter variables as an internal time. More specifically, we have one model in which we have two options as internal time. In this paper we try to solve them and subsequently compare their quantum evolutions. A paper by Styer [2] presents a method that can be expanded to find semi-classical solutions for these two cases. We apply this method and compare the physical predictions that they imply.

This paper is organized as follows. We start by setting up our isotropic cosmological model and defining the classical conditions of this model. We then consider quantization and utilize a Taylor expansion to find approximate solutions. Standard numerical analysis is used to find semi-classical solutions for our equations. We conclude by making comparisons between each matter clock's respective solution and discuss the physical implications of such comparisons.

Methods

Classical Model

If we assume coordinates x^a such that $a=1,2,3$, this implies that the coordinate volume $V_0=\int d^3x$ is dependent on our choice of coordinates. We can make the volume coordinate independent by using a metric tensor h_{ab} and defining $V=\int \sqrt{\det h_{ab}} d^3x$ which instead depends only on the metric. This is considered a physical field in general relativity.

The Friedmann equation for a homogeneous, isotropic, flat chunk of space, ($h_{ab}=a(t)^2 \delta_{ab}$) in Cartesian coordinates is

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3c^2} \rho$$

where $a(t)$ is the scale factor and ρ is the energy density of matter. For our purposes, V is proportional to a^3 . The Friedmann equation is a constraint in quantum cosmology rather than an evolution generator so we have to use a method called deparameterization to determine evolution. The idea of deparameterization is to take a special choice of matter field coupled to space-time so that its homogeneous value can formally play the role of time. The most common example is a free, massless, scalar field ϕ with momentum p_ϕ and energy density $\rho = p_\phi^2/2a^6$.

Then from the Friedmann equation, we get

$$p_\phi(a, p_a) = \sqrt{\frac{4\pi G}{3c^2}} |ap_a|, \quad (V_0 = 1 \text{ for now})$$

It follows that the equations of motion are

$$\frac{da}{d\phi} = \frac{\partial p_\phi}{\partial p_a} = \sqrt{\frac{4\pi G}{3c^2}} a, \quad \frac{dp_a}{d\phi} = \frac{\partial p_\phi}{\partial a} = -\sqrt{\frac{4\pi G}{3c^2}} p_a$$

We now introduce a cosmological constant Λ and have the energy density,

$$\rho = \frac{p_\phi^2}{2a^6} + \Lambda.$$

Substituting this into the first part of the Friedmann equation and solving for p_ϕ gives us

$$p_\phi = \sqrt{2V} \sqrt{\frac{3}{8\pi G} H^2 - \Lambda}$$

Quantization

Now we consider the case where the cosmological constant is an operator,

$$\frac{3}{8\pi G} \hat{H}^2 = \hat{\rho} = \frac{1}{2} \frac{\hat{p}_\phi^2}{\hat{V}^2} + \hat{\Lambda}$$

This is appropriate to do because all commutators are zero. We introduce

$$\hat{C} = -\frac{3}{8\pi G} \hat{H}^2 + \frac{1}{2} \frac{\hat{p}_\phi^2}{\hat{V}^2} + \hat{\Lambda}$$

which is analogous to the Hamiltonian and a dummy variable T such that

$$\hat{\Lambda} = \hat{p}_T = \frac{\hbar}{i} \frac{\partial}{\partial T} \implies \hat{C} = -\frac{3}{8\pi G} \hat{H}^2 + \frac{1}{2} \frac{\hat{p}_\phi^2}{\hat{V}^2} + \frac{\hbar}{i} \frac{\partial}{\partial T}$$

and the condition that

$$\hat{C}\psi = 0 \implies i\hbar \frac{\partial \psi}{\partial T} = \left(-\frac{3}{8\pi G} \hat{H}^2 + \frac{1}{2} \frac{\hat{p}_\phi^2}{\hat{V}^2} \right) \psi$$

Application of Taylor Expansion

We will apply semi-classical methods to the Hamiltonians p_T and p_ϕ :

$$p_T = \frac{3}{8\pi G} H^2 - \frac{1}{2} \frac{p_\phi^2}{V^2}, \quad (p_\phi \text{ const.})$$

$$p_\phi = \sqrt{2V} \sqrt{\frac{3}{8\pi G} H^2 - \Lambda}, \quad (\Lambda \text{ const})$$

These Hamiltonians are not quadratic, which means that the equations obtained following the procedure outlined in Styer's paper [2] cannot be solved exactly. However, we can use several approximations. As a first step, we can use a Taylor expansion to second order, and apply methods as used in [2] to the resulting quadratic expression. We will see differences between using T and ϕ at this level.

Using a Taylor expansion of p to second order, we get

$$\begin{aligned}\hat{p} &= p(\hat{H}, \hat{V}) = p(\langle \hat{H} \rangle + (\hat{H} - \langle \hat{H} \rangle), \langle \hat{V} \rangle + (\hat{V} - \langle \hat{V} \rangle)) \\ &= p(\langle \hat{H} \rangle, \langle \hat{V} \rangle) + \frac{\partial p(\langle \hat{H} \rangle, \langle \hat{V} \rangle)}{\partial \langle \hat{H} \rangle} (\hat{H} - \langle \hat{H} \rangle) + \frac{\partial p(\langle \hat{H} \rangle, \langle \hat{V} \rangle)}{\partial \langle \hat{V} \rangle} (\hat{V} - \langle \hat{V} \rangle) + \frac{1}{2} \left(\frac{\partial^2 p(\langle \hat{H} \rangle, \langle \hat{V} \rangle)}{\partial \langle \hat{H} \rangle^2} (\hat{H} - \langle \hat{H} \rangle)^2 \right. \\ &\quad \left. + \frac{\partial^2 p(\langle \hat{H} \rangle, \langle \hat{V} \rangle)}{\partial \langle \hat{H} \rangle \langle \hat{V} \rangle} ((\hat{H} - \langle \hat{H} \rangle)(\hat{V} - \langle \hat{V} \rangle) + (\hat{V} - \langle \hat{V} \rangle)(\hat{H} - \langle \hat{H} \rangle)) + \frac{\partial^2 p(\langle \hat{H} \rangle, \langle \hat{V} \rangle)}{\partial \langle \hat{V} \rangle^2} (\hat{V} - \langle \hat{V} \rangle)^2 \right) + \dots\end{aligned}$$

Now we have to determine the time derivatives

$$\frac{d\langle \hat{V} \rangle}{dt}, \frac{d\langle \hat{H} \rangle}{dt}, \frac{d\langle \hat{V}^2 \rangle}{dt}, \frac{d\langle \hat{H}^2 \rangle}{dt}, \frac{d\langle \hat{H}\hat{V} + \hat{V}\hat{H} \rangle}{dt}$$

First, we compute the order terms for all of the time derivatives.

$$\begin{aligned}\frac{d\langle \hat{V} \rangle}{dt} &= \sum_{\alpha=1}^7 \frac{\langle [\hat{V}, \hat{p}_\alpha] \rangle}{i\hbar} = \frac{\partial p}{\partial \langle \hat{H} \rangle}, \quad \frac{d\langle \hat{H} \rangle}{dt} = \sum_{\alpha=1}^7 \frac{\langle [\hat{H}, \hat{p}_\alpha] \rangle}{i\hbar} = -\frac{\partial p}{\partial \langle \hat{V} \rangle} \\ \frac{d\langle \hat{V}^2 \rangle}{dt} &= \sum_{\alpha=1}^7 \frac{\langle [\hat{V}^2, \hat{p}_\alpha] \rangle}{i\hbar} = \frac{\partial p}{\partial \langle \hat{H} \rangle} 2\langle \hat{V} \rangle + 2 \frac{\partial^2 p}{\partial \langle \hat{H} \rangle^2} (\langle \hat{V}\hat{H} + \hat{H}\hat{V} \rangle - 2\langle \hat{V} \rangle \langle \hat{H} \rangle) + 2 \frac{\partial^2 p}{\partial \langle \hat{H} \rangle \langle \hat{V} \rangle} (\langle \hat{V}^2 \rangle - \langle \hat{V} \rangle^2) \\ \frac{d\langle \hat{H}^2 \rangle}{dt} &= \sum_{\alpha=1}^7 \frac{\langle [\hat{H}^2, \hat{p}_\alpha] \rangle}{i\hbar} = -\frac{\partial p}{\partial \langle \hat{H} \rangle} 2\langle \hat{H} \rangle - 2 \frac{\partial^2 p}{\partial \langle \hat{H} \rangle \langle \hat{V} \rangle} (\langle \hat{H}^2 \rangle - \langle \hat{H} \rangle^2) \\ \frac{d\langle \hat{H}\hat{V} + \hat{V}\hat{H} \rangle}{dt} &= \sum_{\alpha=1}^7 \frac{\langle [\hat{H}\hat{V} + \hat{V}\hat{H}, \hat{p}_\alpha] \rangle}{i\hbar} = \frac{\partial p}{\partial \langle \hat{H} \rangle} 2\langle \hat{H} \rangle - \frac{\partial p}{\partial \langle \hat{V} \rangle} 2\langle \hat{V} \rangle + \frac{\partial^2 p}{\partial \langle \hat{H} \rangle^2} 4(\langle \hat{H}^2 \rangle - \langle \hat{H} \rangle^2) + \frac{\partial^2 p}{\partial \langle \hat{V} \rangle^2} 2(\langle \hat{V}^2 \rangle - \langle \hat{V} \rangle^2)\end{aligned}$$

For the V and H expectation value derivatives, we will consider the third order terms of the Taylor expansion.

$$\begin{aligned}\frac{d\langle \hat{V} \rangle}{dt} &= \sum_{\alpha=1}^{11} \frac{\langle [\hat{V}, \hat{p}_\alpha] \rangle}{i\hbar} = \frac{\partial p}{\partial \langle \hat{H} \rangle} + \sum_{\alpha=8}^{11} \frac{\langle [\hat{V}, \hat{p}_\alpha] \rangle}{i\hbar} \\ \frac{d\langle \hat{H} \rangle}{dt} &= \sum_{\alpha=1}^{11} \frac{\langle [\hat{H}, \hat{p}_\alpha] \rangle}{i\hbar} = -\frac{\partial p}{\partial \langle \hat{V} \rangle} + \sum_{\alpha=8}^{11} \frac{\langle [\hat{H}, \hat{p}_\alpha] \rangle}{i\hbar}\end{aligned}$$

Explicitly, the third order terms of the Taylor expansion are

$$\begin{aligned}
p_8 + p_9 + p_{10} + p_{11} &= \frac{1}{6} \frac{\partial^3 p(\langle \hat{H} \rangle, \langle \hat{V} \rangle)}{\partial \langle \hat{H} \rangle^3} (\hat{H} - \langle \hat{H} \rangle)^3 + \frac{1}{6} \frac{\partial^3 p(\langle \hat{H} \rangle, \langle \hat{V} \rangle)}{\partial \langle \hat{V} \rangle^3} (\hat{V} - \langle \hat{V} \rangle)^3 \\
&+ \frac{1}{6} \frac{\partial^3 p(\langle \hat{H} \rangle, \langle \hat{V} \rangle)}{\partial \langle \hat{H} \rangle^2 \partial \langle \hat{V} \rangle} \left((\hat{H} - \langle \hat{H} \rangle)^2 (\hat{V} - \langle \hat{V} \rangle) + (\hat{H} - \langle \hat{H} \rangle) (\hat{V} - \langle \hat{V} \rangle) (\hat{H} - \langle \hat{H} \rangle) + (\hat{V} - \langle \hat{V} \rangle) (\hat{H} - \langle \hat{H} \rangle)^2 \right) \\
&+ \frac{1}{6} \frac{\partial^3 p(\langle \hat{H} \rangle, \langle \hat{V} \rangle)}{\partial \langle \hat{H} \rangle \partial \langle \hat{V} \rangle^2} \left((\hat{H} - \langle \hat{H} \rangle) (\hat{V} - \langle \hat{V} \rangle)^2 + (\hat{V} - \langle \hat{V} \rangle) (\hat{H} - \langle \hat{H} \rangle) (\hat{V} - \langle \hat{V} \rangle) + (\hat{V} - \langle \hat{V} \rangle)^2 (\hat{H} - \langle \hat{H} \rangle) \right)
\end{aligned}$$

After solving, we see that the third order time derivative solutions are as follows

$$\begin{aligned}
\frac{d\langle \hat{V} \rangle}{dt} &= \sum_{\alpha=1}^{11} \frac{\langle [\hat{V}, \hat{p}_\alpha] \rangle}{i\hbar} = \frac{\partial p}{\partial \langle \hat{H} \rangle} + \sum_{\alpha=8}^{11} \frac{\langle [\hat{V}, \hat{p}_\alpha] \rangle}{i\hbar} \\
&= \frac{\partial p}{\partial \langle \hat{H} \rangle} + \frac{1}{6} \left(\frac{\partial^3 p}{\partial \langle \hat{H} \rangle^3} (3(\langle \hat{H}^2 \rangle - \langle \hat{H} \rangle^2)) + \frac{\partial^3 p}{\partial \langle \hat{H} \rangle^2 \partial \langle \hat{V} \rangle} (3(\langle \hat{H} \hat{V} \rangle - 2\langle \hat{H} \rangle \langle \hat{V} \rangle + \langle \hat{V} \hat{H} \rangle)) + \frac{\partial^3 p}{\partial \langle \hat{H} \rangle \partial \langle \hat{V} \rangle^2} (3(\langle \hat{V}^2 \rangle - \langle \hat{V} \rangle^2)) \right) \\
\frac{d\langle \hat{H} \rangle}{dt} &= \sum_{\alpha=1}^{11} \frac{\langle [\hat{H}, \hat{p}_\alpha] \rangle}{i\hbar} = -\frac{\partial p}{\partial \langle \hat{V} \rangle} + \sum_{\alpha=8}^{11} \frac{\langle [\hat{H}, \hat{p}_\alpha] \rangle}{i\hbar} = \frac{\partial p}{\partial \langle \hat{H} \rangle} + \frac{1}{6} \left(\frac{\partial^3 p}{\partial \langle \hat{H} \rangle^3} (0) + \frac{\partial^3 p}{\partial \langle \hat{V} \rangle^3} (-3(\langle \hat{V}^2 \rangle - \langle \hat{V} \rangle^2)) \right) \\
&\quad + \frac{\partial^3 p}{\partial \langle \hat{H} \rangle^2 \partial \langle \hat{V} \rangle} (-3(\langle \hat{H}^2 \rangle - \langle \hat{H} \rangle^2)) + \frac{\partial^3 p}{\partial \langle \hat{H} \rangle \partial \langle \hat{V} \rangle^2} (-3(\langle \hat{H} \hat{V} \rangle - 2\langle \hat{H} \rangle \langle \hat{V} \rangle + \langle \hat{V} \hat{H} \rangle))
\end{aligned}$$

Analytical and Numerical Solutions

With the Taylor expansion completed and the time derivatives solved for algebraically, we can substitute our choices for p , namely p_T and p_ϕ , to find dV/dt for each case. After resolving and simplifying the derivatives, we get

$$\begin{aligned}
\frac{dV}{dT} &= \frac{3}{4\pi G} H \\
\frac{dV}{d\phi} &= \frac{3HV}{4\pi G \sqrt{\frac{3H^2}{4\pi G} - \Lambda}} \\
&\quad + \frac{1}{6} V \frac{27H\Lambda}{(4\pi G)^2 (\frac{3H^2}{4\pi G} - \Lambda)^{5/2}} h_2 \\
&\quad + \frac{1}{6} \left(\frac{3}{4\pi G} \right)^2 \frac{H}{(\frac{3H^2}{4\pi G} - \Lambda)^{3/2}} \left(\frac{\frac{3H^2}{4\pi G} + \Lambda}{\frac{3H^2}{4\pi G} - \Lambda} \right) h_3
\end{aligned}$$

We can see that $dV/d\phi$ has a much more complicated form than does dV/dT . However, observe that the second term in $dV/d\phi$ approaches zero and the third term is of order $1/H^2$ for small Λ . This is a reasonable approximation due to the fact that the observed cosmological constant is very small. As a result, we exclude the second and third terms from $dV/d\phi$ for our purposes. We will check this approximation numerically.

For the cases of $dH/d\phi$ and dH/dT , we get

$$\frac{dH}{dT} = \frac{p_\phi^2}{V^3} + \frac{2h_1 p_\phi^2}{V^5}$$

$$\frac{dH}{d\phi} = \sqrt{\frac{3H^2}{4\pi G} - \Lambda} - \frac{1}{6} \left(\frac{3}{4\pi G} \right)^2 \frac{H}{\left(\frac{3H^2}{4\pi G} \right)^{3/2} - \Lambda} \left(\frac{3H^2}{4\pi G} + \Lambda \right) h_3$$

Observe that for dH/dT , the second term decays as $1/V^5$. So for large V (an older universe), the second term is much smaller than the first. The second term in $dH/d\phi$ is approximately zero due to the same reasoning as in the case of $dV/d\phi$.

$$\frac{dV}{dT} = \frac{3}{4\pi G} H, \quad \frac{dH}{dT} = \frac{p_\phi^2}{V^3}$$

$$\frac{d^2V}{dT^2} = \frac{3}{4\pi G} \frac{dH}{dT} \rightarrow \frac{d^2V}{dT^2} = \frac{3}{4\pi G} \frac{p_\phi^2}{V^3}$$

We solve for V and dV/dT .

$$V = \sqrt{\frac{1 + t^2 C_1^2 + 2t C_1^2 C_2 + C_1^2 C_2^2}{C_1}}$$

$$\frac{dV}{dT} = \frac{t C_1^2 + C_1^2 C_2}{\sqrt{C_1} \sqrt{1 + t^2 C_1^2 + 2t C_1^2 C_2 + C_1^2 C_2^2}} = \frac{3}{4\pi G} H$$

After solving $V_0 = V(0)$ and $H_0 = H(0)$, we get

$$C_1 = \frac{1 + V_0^2 H_0^2}{V_0^2}, \quad C_2 = \frac{H_0/V_0}{1 + V_0^2 H_0^2}$$

Now we have to transition to proper time.

$$\frac{dT}{d\tau} = V$$

Integrating $dT/d\tau$ gives us

$$T(\tau) = \frac{1}{C_1} \sinh(\sqrt{C_1} \tau) - C_2$$

$$\frac{dV}{dT} = \frac{3H}{4\pi G} \rightarrow \frac{dV}{d\tau} = \frac{3}{4\pi G} HV$$

$$\frac{\dot{V}}{V} = \frac{3}{4\pi G} H \quad (1)$$

Now we consider the ϕ system.

$$\frac{dV}{d\phi} = \frac{3HV}{4\pi G \sqrt{\frac{3H^2}{4\pi G} - \Lambda}}$$

$$\frac{dH}{d\phi} = -\sqrt{\frac{3H^2}{4\pi G} - \Lambda}$$

$$\frac{d\phi}{d\tau} = \frac{p_\phi}{V}$$

One can still solve for V and H , but the process is much longer. Instead of solving the ϕ equations, one can look at the equations and rewrite $dV/d\phi$ as the expansion rate.

$$\frac{dV}{d\phi} = \frac{3HV}{4\pi G \sqrt{\frac{3H^2}{4\pi G} - \Lambda}}$$

$$\frac{dV}{d\tau} = \frac{3Hp_\phi}{4\pi G \sqrt{\frac{3H^2}{4\pi G} - \Lambda}}$$

$$\frac{\dot{V}}{V} = \frac{3}{4\pi G} H \quad (2)$$

Since proper time is measured, it should be the same between reference frames. Classically, V/V is indeed the same between our two frames. This can be seen by comparing (1) and (2).

As we bring in the quantum correction terms to the T system, the V equation is unchanged, but the H equation is changed. In the ϕ system, both equations change. Even though (1) and (2) are the same classically, they will be different when quantum correction terms are introduced.

Discussion and Conclusions

As the main result, we have shown that the quantum corrections result in differences between the T and ϕ systems. This result is independent of the approximations made in the Analytical and Numerical Solutions section. If one were interested in complete solutions, one would have to use approximations or full numerics.

After resolving the derivatives from the Taylor expansion, the constant terms h_1 , h_2 , and h_3 made it impossible to find closed form solutions for our equations. Because of this, we used numerics to find solutions. We used Mathematica's standard procedure for numerical analysis and were able to determine appropriate initial conditions for our systems.

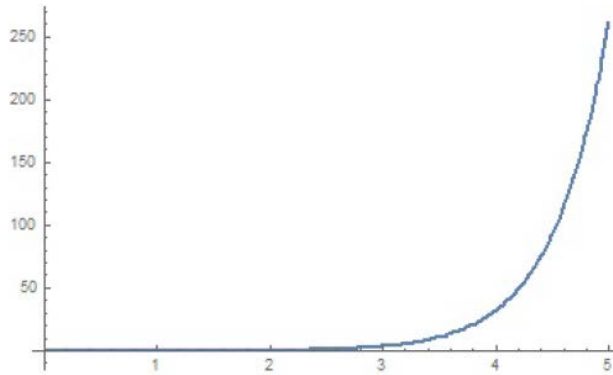


FIG. 1. $(\Delta V)^2$ as a function of τ

Figure 1. Plots the volume fluctuations of the universe with respect to time. The fluctuations grow rapidly, which may not be expected in a classical universe. However, the volume expectation value is increasing as well.

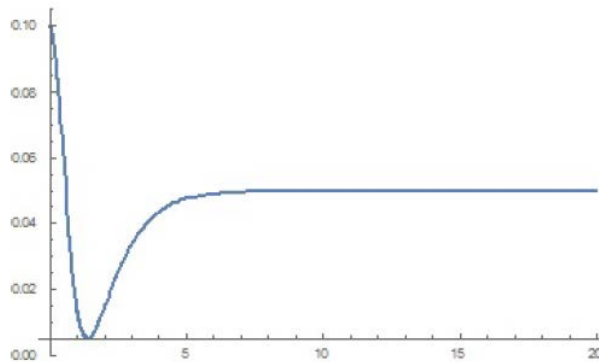


FIG. 2. $(\Delta V)^2/V^2$ as a function of τ

Figure 2. Plots the volume fluctuations of the universe over the volume of the universe with respect to proper time. This agrees with semi-classical behavior because the ratio $(\Delta V)^2/V^2$ is a small constant at large τ . Qualitatively, this agrees with the observed universe.

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Bumblebee Thermoregulation: Understanding the thermal properties of physical features of bumblebees

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Abstract

Temperature regulation plays an essential role in bumblebees because they need a specific range of temperatures to forage without overheating. Although physiological mechanisms that allow bees to regulate their temperature have been studied, how physical features of bumblebees influence their thermoregulation abilities is still not well understood. This study examined which physical features of bumblebees- color, pile density and length, and size- affect bumblebee temperatures the most when they heat from sunlight exposure. Temperature data was examined from thermal images of 130 bumblebees of 11 different species as they heated under a lamp. The results showed that pile length and color played a significant role in passive heating of bumblebees while the roles of the other factors studied were found to be insignificant. Even small effects of physical features may be favored in particular climates and may have helped drive diversity in bumblebee color and pile properties globally.

Introduction

Thermoregulation is a process that allows the body of an organism to maintain its core body temperature even under extreme conditions such as tropical heat and Arctic cold. This body function has been adapted by several species to ensure their survival under varying environmental conditions. One of the species that uses thermoregulation as a basis to survive are bumblebees. Thermoregulation allows bees to control the heat that spreads throughout their thorax and abdomen as they contract their muscles to fly. Higher thoracic temperatures help bumblebees to forage faster and more efficiently (Heinrich 1996). Maintaining a stable internal temperature is important for bumblebees because it allows them to not overheat when they use energy to forage for food.

Bombus species are notorious for possessing convergent color patterns (Owen 1980). There are over 250 bumblebee species with different color forms (Williams 2007). Bumblebee diversity was studied and found to affect the loss rate of bumblebee workers during foraging (Chittka 2014). Bumblebee colors and color patterns are also thought to have an aposematic or warning function, and this has led to the evolution of mimicry in bumblebees (Steltzer 2010). Studies done by Stiles suggest that bumblebee color diversity may be caused by thermal properties as well as mimicry (Stiles 1979). Thermal properties could play a role in bumblebees using coloration to adapt to various climates (Stiles 1979). Williams found that bumblebees with

all black or mostly black pile are found in tropical environments, bumblebees with red pile are found in the highlands, and bumblebees with more pale yellow and yellow pile are found in mid-temperate environments (Williams 2007). It is argued that in climates like the tropics where the day to day temperature is consistent, bumblebees with black hair are advantageous (Williams 2007). In climates where the temperature varies daily, bumblebees are seen with a lot of pale yellow and yellow pile (Heinrich 1996). Bumblebees adapt and use color diversity to avoid predators but this adaptation could also help bees adapt to extreme conditions if coloration plays a role in bumblebee thermoregulation (Williams 2007). Color traits may affect the ability to cool and heat the body of a bumblebee and therefore may be adaptive for optimizing foraging.

This study examines the relative contribution of physical traits to thermal properties in bumblebees such as pile length, pile density, size, and color. These features vary from species to species when considering the bumblebee population so observing how different species with different traits heat and cool would help give evidence to support that thermoregulation can be enhanced or reduced based on contrasting bumblebee properties. There are currently no studies that show the systematic differences of the effect of either coat color or coat length on temperature excess in bumblebees of different species (Heinrich 1996). The physical effects of color on bumblebee thermoregulation are not yet well understood, particularly when this involves the differences in pile density and size of bumblebee species (Williams 2007). There are predictions based on wind tunnel insulation experiments that pile density is more important in thermoregulation than pile length (Heinrich 1993). Size is one of the major restrictions in regulating high body temperatures (Heinrich 1983). Studies looking at the role bee size plays in thermoregulation have shown that smaller bees have a relatively higher warm-up rate per mass unit than bigger bees (Heinrich 1983). Thoracic temperatures measured during free flight in the field correlated positively with the bees' body mass (Stone 1993). Bees with long hair are better able to keep themselves warm during cold nights but they also struggle with heat stress during hot days (Stiles 1949).

This research project will help to understand which physical properties of bumblebees play the biggest role in thermoregulation and are most advantageous to these bees. It is important to study the effect of thermoregulation on bees because thermoregulation is essential for their ability to efficiently forage and foraging is one of the keys to bumblebees' survival. It is suggested that greater foraging rates of large bees are due to their high thermoregulation abilities in cooler temperatures (Heinrich 1993). Body temperature also affects bees' energy rates and ability to avoid predators (Heinrich 1974).

This thermoregulation research project is building on past research on the effects of coloration on thermoregulatory properties and expanding it to include the pile length, pile density, and size of these bumblebees. Even a small change in color variation, size, pile density, or pile length could have a big impact on thermoregulation which is a possible explanation for why bumblebee species that have differences in these traits thermoregulate at disparate rates. In this study, we used infrared imagery of bees under a full-spectrum lamp to understand which of the factors studied-body size, pile density, pile length, and color- impact bumblebee heating the most and therefore have been most important in their adaptation. This research will be a significant step towards understanding role of external features on thermal properties and adaptation of these bees.

Materials and Methods

Cuticle Experiment

Before examining the thermal properties of whole bumblebees, the thermoregulatory properties of different colored pile on bumblebees were studied using cuticle sample pieces from bees. An analysis was performed of small pieces of dissected cuticle of standard size. Cuticle pieces were obtained from *Bombus huntii* and *Bombus impatiens* by cutting a $0.4 \times 0.3 \mu\text{m}$ piece of abdominal cuticle off of each bumblebee. In total 10 black cuticle pieces, 10 yellow cuticle pieces, and 10 red cuticle pieces were used. The samples were arranged in a circle in a Styrofoam box and a piece of paper separated these samples from the lamp to help diffuse the light. A 1-inch circular gap in the paper was cut out for the infrared camera to capture images. A Philips Duramax 45W indoor flood light bulb was used in this research because it best emulated sunlight and contained infrared wavelengths. The light bulb was placed 20 cm above the cuticle pieces. The FLIR C2 Compact Imaging System was the camera used for these experiments, it took infrared images and could pinpoint the temperature of the samples that the images captured. The FLIR C2 camera was set up to take MSX images from a distance of < 1 m according to the instructions found in the Flir User Documentation Manual, included with FLIR C2 camera (FLIR Manual 6). After the light bulb was turned on an image was taken immediately, then an image was taken of the cuticle every 5 seconds for the first minute, every 10 second for the next four minutes, and every minute for the last 5 minutes (see Fig. 1).

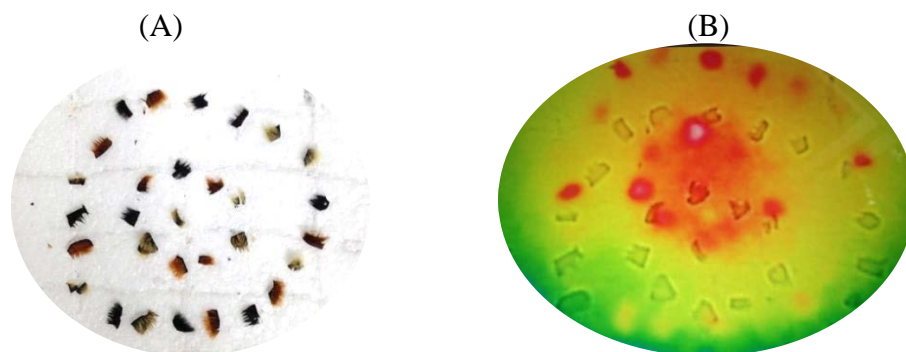


Figure 1: Design of standard cuticle piece experiment. (A) Black, red, and yellow cuticle pieces ($0.4\mu\text{m} \times 0.3\mu\text{m}$) were arranged in random order in a Styrofoam box. (B) An infrared image of the assorted cuticle pieces taken using the FLIR C2 Camera.

Preservation Experiment

Different preservation methods were tested to see if preservation methods affected how whole bumblebees heated. This experiment guided the choice of preservation technique for subsequent experiments. We used three dead queen *Bombus impatiens* for each preservation type and removed their wings (see Fig. 2A-2C). Preservation techniques included a dry bee (sitting out at room temperature for weeks), ethanol preserved bee (dipped in ethanol then dried at room temperature for an hour and a half) and freshly frozen bee (taken out of the freezer twenty minutes before the heating experiment was carried out until all the moisture had evaporated). Each of the three bees had two replicates and each bee was placed in the same Styrofoam box setup used for the cuticle experiment. A Styrofoam box was used because it best

insulated the heat radiated from the light bulb. The bees were pinned to hold them in place. The same heating process used for the cuticle experiment was used for testing preservation methods, an image was taken immediately after the light bulb was turned on then every 5 seconds for the first minute, every 10 second for the next four minutes, and every minute for the last 5 minutes (see Fig. 2D).

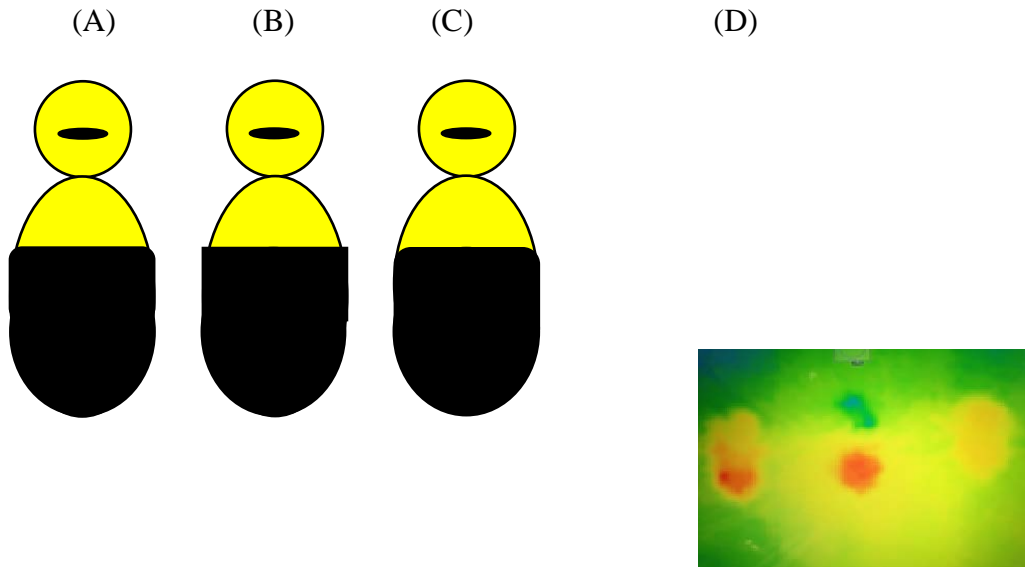


Figure 2: Design of Preservation Experiment: Queen *Bombus impatiens* preserved three different ways. (A) dry bee, (B) ethanol preserved bee, (C) freshly frozen bee. (D) Infrared image taken of the three *B. impatiens* at the 5 minute timepoint. Preservation methods impact bee temperature.

Role of Physical Properties on Whole Bees Heating

The roles that size, coloration, pile density, and pile length of bumblebees played on their thermal properties were examined by taking bees with differences in these factors and putting them in a heating and cooling experiment. Bumblebees were obtained from two local communities in central Pennsylvania, Bellefonte at a cidery and State College at the Pennsylvania State University's Arboretum, and from field sites in two other states, Oregon and California. The species studied in this experiment were *B. impatiens*, *Bombus centralis*, *B. huntii*, *Bombus melanopygus*, *Bombus mixtus* workers, *Bombus ternarius*, *Bombus bimaculatus*, *Bombus perplexus*, *Bombus griseocollus*, *Bombus bifarius*, and *Bombus vosnesenskii* with 130 bumblebees total (see Appendix). To prepare the bumblebees for the main experiment the wings and legs of each bee were removed. The whole bumblebees used were dead so that the temperature of each bee could be located and other outside factors did not affect the heating process.

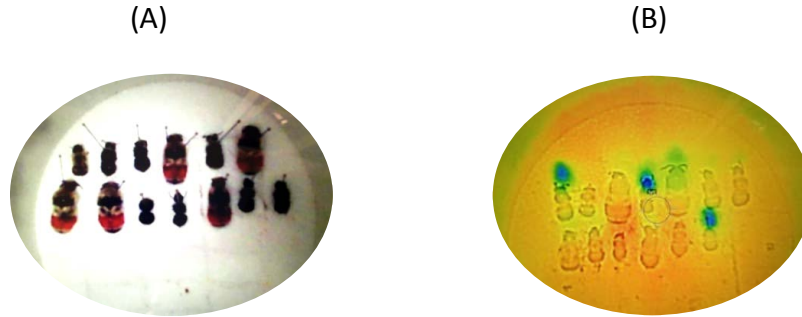


Figure 3: Design for Whole Bee Heating Experiment (A) is one of the trials used for the whole bee heating experiment. There were 13 bees in each trial with 10 trials total. The bees were arranged randomly and pinned down through their thorax in the same container used in the previous experiments. evenly. (B) Infrared image taken of one of the trials used for heating whole bees.

The thermoregulation experiments were carried out under a surface light bulb using the FLIR C2 infrared camera to locate and process the temperature of each individual bee while the surface light bulb simulated sunlight to heat the bumblebees. These experiments were carried out 10 times with 13 bees placed at random in each trial. The bumblebees were placed into two rows and pinned on both sides of the abdomen and underneath the thorax in the same Styrofoam box used before so that the infrared camera could properly capture the temperature of each bee without light dispersion being a complication (see Fig. 3A). A plastic cylinder was placed over the bumblebees in the box so the FLIR C2 camera could fit into the hole that the cylinder made and capture thermal images. The FLIR C2 camera was set to take images from a distance of < 1 m and the display temperature setting was used (FLIR Manual 6). An image was taken immediately after the light bulb was turned on. After the first image, an image was taken of the thirteen bumblebees every 20 seconds for the first minute then every minute for the next nine minutes (see Fig. 3B). This allowed the camera to have more time to calibrate between images, avoiding too many environmental temperature fluctuations in the data. All of the images were uploaded and analyzed in FLIR Tools on a Surface Pro 3.

Each bumblebee was phenotyped after the heating experiment was finished. Size was accounted for by measuring the intertegular distance of each bee (Cane 1987). Pile length was measured by taking 4-6 individual hairs off of the top of the thorax and the first segment of the abdomen and finding their length under a microscope then averaging the lengths of all the hairs obtained. It was found that the length of hairs on the thorax was the same on the abdomen for each species. Pile density was found a similar way by shaving hair from a 0.5 μm cuticle area off of the top of the thorax and the second segment of the abdomen then counting how many hairs were in each area. The percentage of each color was found by making a color map of each species used in the whole bee heating experiment (see Appendix).

Results

Results were obtained from the heating experiments on bumblebee cuticle pieces, bumblebees preserved different ways, and the total of 130 bumblebees used for studying different physical features of whole bumblebees. The average heating curve of the different colored cuticle pieces studied was calculated (see Fig. 4) and this curve displayed that the black cuticle pieces heated more overall than both the yellow and red pieces. There was a 1°F difference between the black cuticle pieces and the red and yellow ones. The curve also showed that red and yellow cuticle pieces heated similarly throughout the experiment, there was only a

0.1°F difference between these two samples, with red cuticle heating more than yellow cuticle. As seen in Fig. 5, preserving bumblebees different ways did have an impact on the amount of heat they displaced. The dry bee heated with a larger degree of difference than both the freshly frozen and ethanol preserved bees (see Fig. 5). For the main experiment, the physical features of whole bumblebees were compared to the temperature of the bees at 240 seconds which was in the middle of the experiment. Bee size (see Fig. 7), Black coloration in the thorax and the abdomen (see Fig. 8), Pile length (see Fig. 9), Pile density in the thorax and the abdomen (see Fig. 10), and starting temperature for each trial (see Fig 11) all were compared to temperature and analyzed using a multiple regression.

The multiple regression was done in Statistical Package for the Social Sciences Software. The multiple regression compared the temperature at 240 seconds which was in the middle of the experiment, to each of the physical features studied individually. The temperature at 240 seconds was also compared to the starting temperature for each trial and each trial itself to see if these factors impacted temperature as well. The multiple regression found the p-value of each factor to see if it was significant. When the multiple regression analysis was studied (see Fig. 6), black coloration in the thorax and pile length were the only physical features that had significant p-values. Pile length had the biggest impact on temperature out of all of the physical properties with a p-value of 0.001 followed by black coloration in the thorax which had a p-value of 0.038. The trials and starting temperatures of each trial were shown to have significant p-values as well, both had p-values of < 0.001.

Average Heating Curve for Different Colored Cuticle Pieces

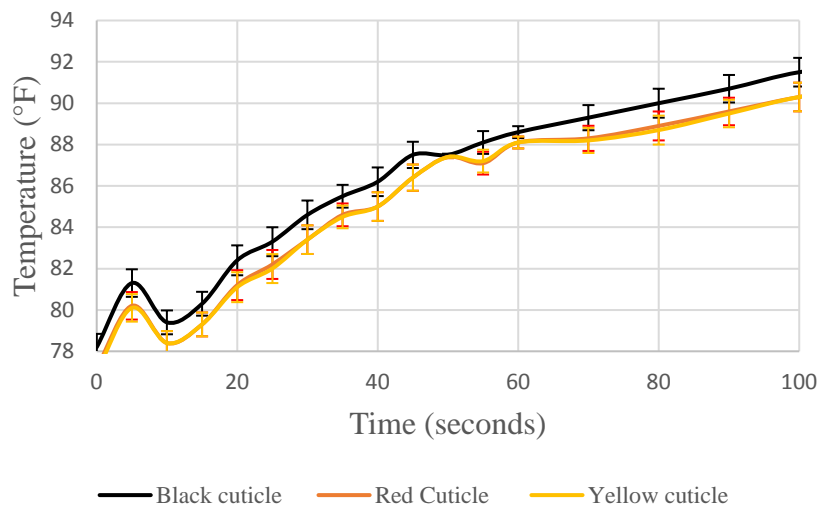


Figure 4: Average heating curve for the black, red, and yellow cuticle pieces (3µm x 4µm). The temperature of each cuticle piece in thermal images using FLIR Tools Software. Black cuticle pieces had a large degree of difference compared to the red and yellow cuticle pieces. Red and yellow cuticle pieces had a small degree of difference between each other.

Average Heating Curve of Bumblebees
Preserved using Different Methods (Dry bee v.
Ethanol preserved bee v. Freshly Frozen bee)

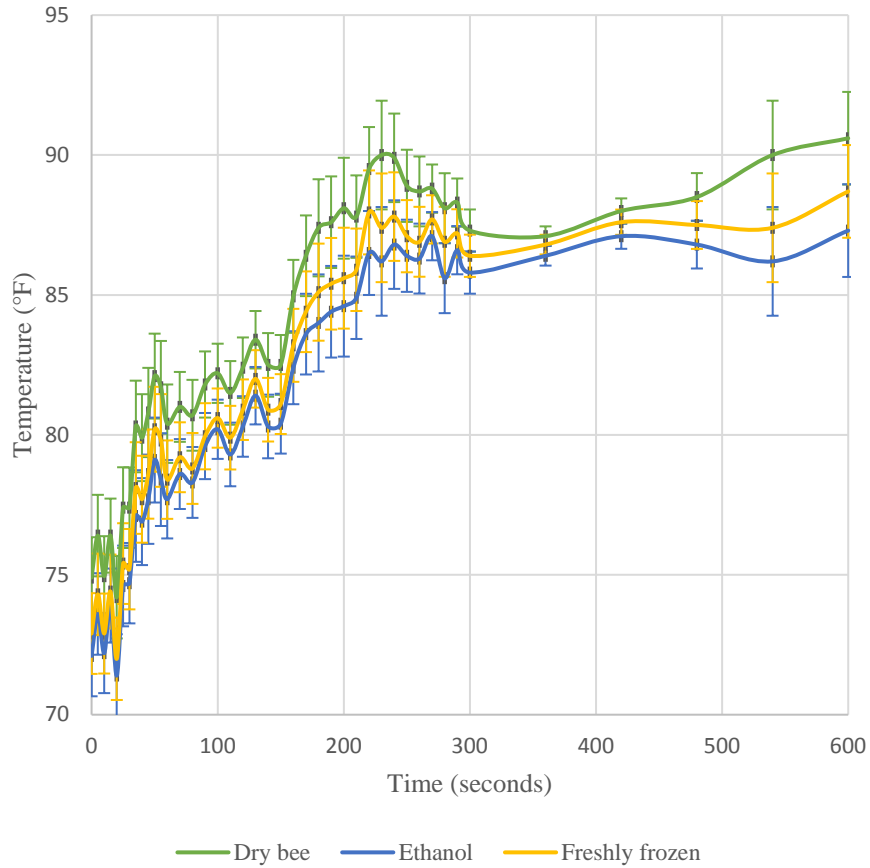


Figure 5: Average heating curve for dry, ethanol, and freshly frozen preserved whole bumblebees. Temperatures were taken from infrared images over time while they were heating under a lamp. Preservation method did impact heating since each bee heated differently. The dry bee had a large degree of temperature difference compared to the other preservation methods studied.

Multiple Regression Analysis for All Physical Features Studied including Trial and Starting Temperature for each Trial

Model	Significance (p-value)
Starting Temperature	0
Size	0.941
Black in Thorax	0.038
Black in Abdomen	0.111
Yellow in Abdomen	0.245
Pile length	0.001
Pile density (Thorax)	0.215
Trial	0

Figure 6: Multiple Regression Analysis. This model was made using a multiple regression statistical analysis to find out if the physical features studied (size, pile length & density, color) had significant p-values and therefore impacted temperature. Starting room temperature and trial were also studied to see if they impacted temperature. From the results shown black coloration in the thorax, pile length, trial, and starting room temperature had significant p-values and therefore influenced heating in this experiment.

Temperature at 240 seconds v. Size

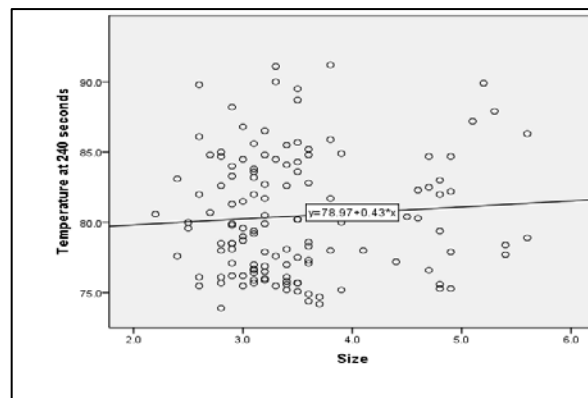


Figure 7: Temperature at 240 seconds v. Size. This figure compares the size of the bees in each trial to their temperature at 240 seconds to see if size impacted the temperature at this time. The size was found to be insignificant.

Temperature at 240 seconds v. Black Coloration in the Thorax and Abdomen

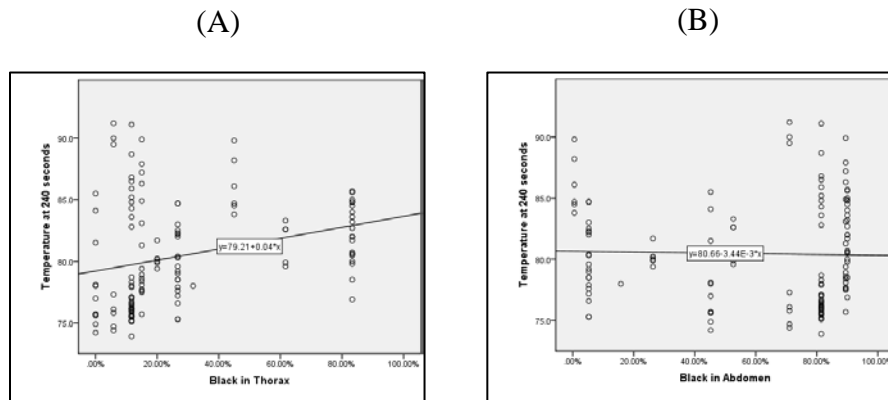


Figure 8: Temperature at 240 seconds v. Black Coloration in the Thorax and Abdomen. This figure compares the black coloration in the thorax (A) and abdomen (B) of the bees in each trial to their temperature at 240 seconds to see if black coloration impacted the temperature at this time. The black coloration in the abdomen (B) was found to be insignificant, therefore it did not influence the temperature of each bee. Black coloration in the thorax (A) was significant ($p = 0.038$).

Temperature at 240 seconds v. Pile length

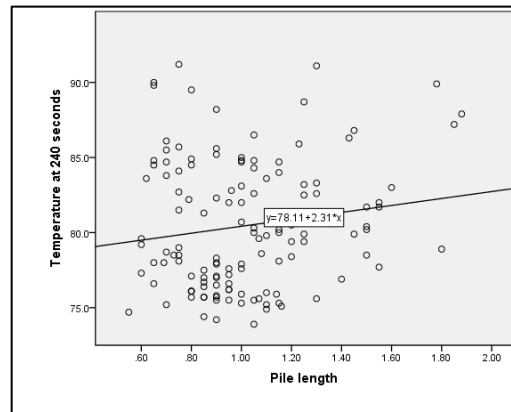


Figure 9: Temperature at 240 seconds v. Pile length. This figure compares the pile length of the bees in each trial to their temperature at 240 seconds to see if pile length impacted the temperature at this time. The pile length was found to be significant ($p = .001$)

Temperature at 240 seconds v. Pile density of the Thorax and Abdomen

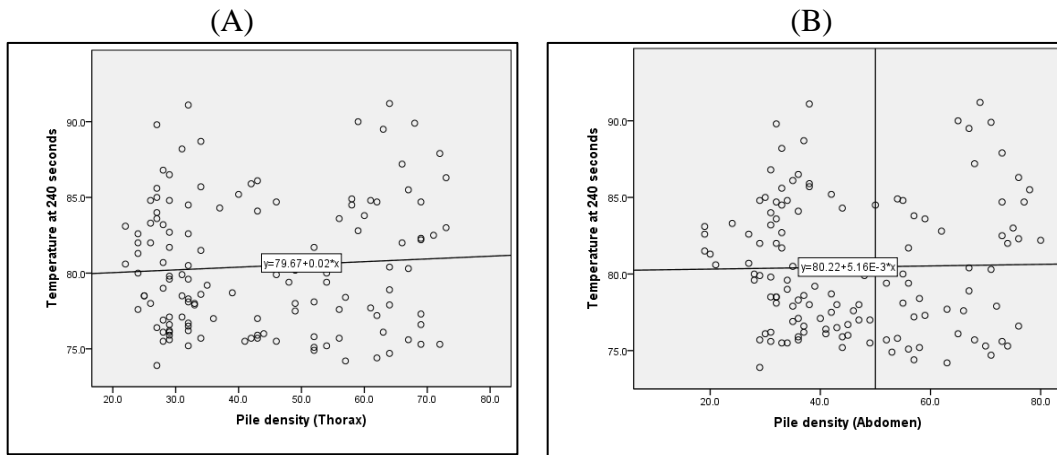


Figure 10: Temperature at 240 seconds v. Pile density of the Thorax and Abdomen. This figure compares the pile density of the thorax (A) and the pile density of the abdomen (B) of the bees in each trial to their temperature at 240 seconds to see if pile density impacted the temperature at this time. Pile density was found to be insignificant.

Temperature at 240 seconds v. Starting Temperature for each Trial

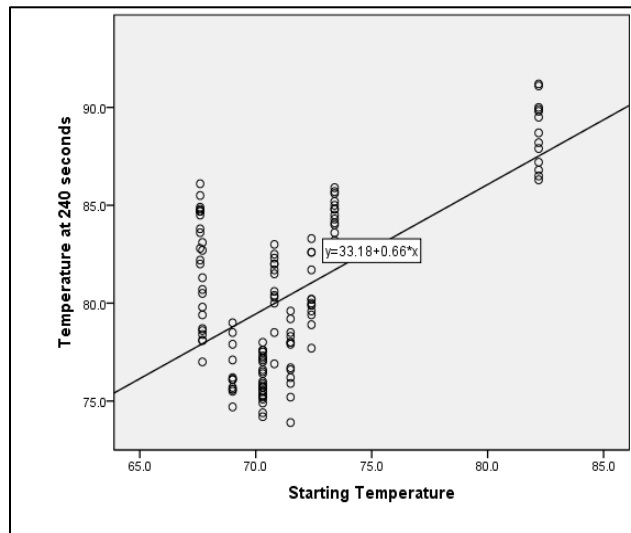


Figure 11: Temperature at 240 seconds v. Starting Temperature for each Trial. The starting temperatures for each trial were looked at to see if they had an impact on the temperature at 240 seconds. The starting temperatures were found to be significant ($p = 0.00$) so they did influence the overall temperature of each bee. This shows that trials must be done on the same day consecutively to negate the trial effect.

Discussion

The results from the cuticle experiment suggest that coloration plays a role in thermoregulation but whole bees were also studied to see if color impacted temperature when the bees had their internal tissue intact. The preservation methods experiment was carried out to see if preserving bees different ways impacted their heating process. This experiment suggested that preservation methods did impact heating because each bee did not heat the same way when they were preserved differently. The dry bee heated with to a larger degree than the freshly frozen and ethanol preserved bees and the ethanol preserved bee heated to a smaller degree than the bees preserved using other methods. Since preservation methods impacted heating, freshly frozen bees were chosen to be used in the main experiment studying the thermal properties of whole bees because they best emulated live bees from the wild.

This study investigated which physical features of bumblebees impacted temperature regulation. Although the process of thermoregulation is understood, the physical factors that affect it have not been studied so this project worked to fill in those research gaps. From the multiple regression statistical analysis done comparing the impact that each physical feature- size, pile density, pile length, and color- had on the temperature of each bee. Pile length was shown to be the most significant and therefore had the biggest impact on the heating process. Color was also significant but had a smaller contribution.

This provides further evidence to the suggestion that color diversity could possibly be caused by a combination of mimicry and thermoregulation (Stiles 1979). Different colored bumblebee pile could be advantageous in different climates, which would explain why completely black and mostly black bumblebees are typically found near the equator, whereas lighter colored bees tend to be found in mid-latitudes (Heinrich 1996).

Conclusion

Previously the effect of physical features of bumblebees on thermoregulation had been studied using correlation to mimicry but not studied individually. This research is provides empirical evidence that different physical properties of bumblebees effect thermoregulation in their bodies. The p-values found for both pile length and color were significant and also much lower than the p-value for pile density suggesting that pile length and color impact temperature more than pile density. Size was also found to not be significant compared to the temperature, revealing that it is less important than color and pile properties. Since pile length was shown to have a large influence on temperature, there is a possibility that insulation effects can help control temperature with shorter pile enabling more heating than longer pile, which may retain internal temperature better.

A limitation of this study was the highly significant impact of trial on temperature. This shows that each trial for the experiment must be considered separately and cannot be considered together since each trial started and ended at different temperatures. One source of this error is that the trials were not done on the same day and therefore had different starting temperatures and humidity. This is further supported by the significant role of starting temperature on heating (see Figure 11). Another source of error could be that not all the moisture evaporated out of each bee at the same rate for each trial, which would have a major impact on their heating.

For future directions, to obtain more cogent results this experiment could be repeated measuring the heat of multiple whole bees in one trial to get rid of trial effect. After that experiments to understand how color effects thermoregulation could be done by studying live bees. One way to do this would be by putting bumblebees of different species with different

color forms into a heat chamber and measuring the rate and at what temperature they knockout to see how different color forms affect how much heat they can withstand in a certain amount of time (Martinet 2015). Although there is more research to be done, the results of this project suggest a correlation between thermoregulation and coloration in bumblebees.

Acknowledgements

This research was supported by the NSF CAREER Award to Hines DEB #1453473 and the McNair Scholars Program.

Appendix Physical Features and Temperatures of Different Bumblebee Species

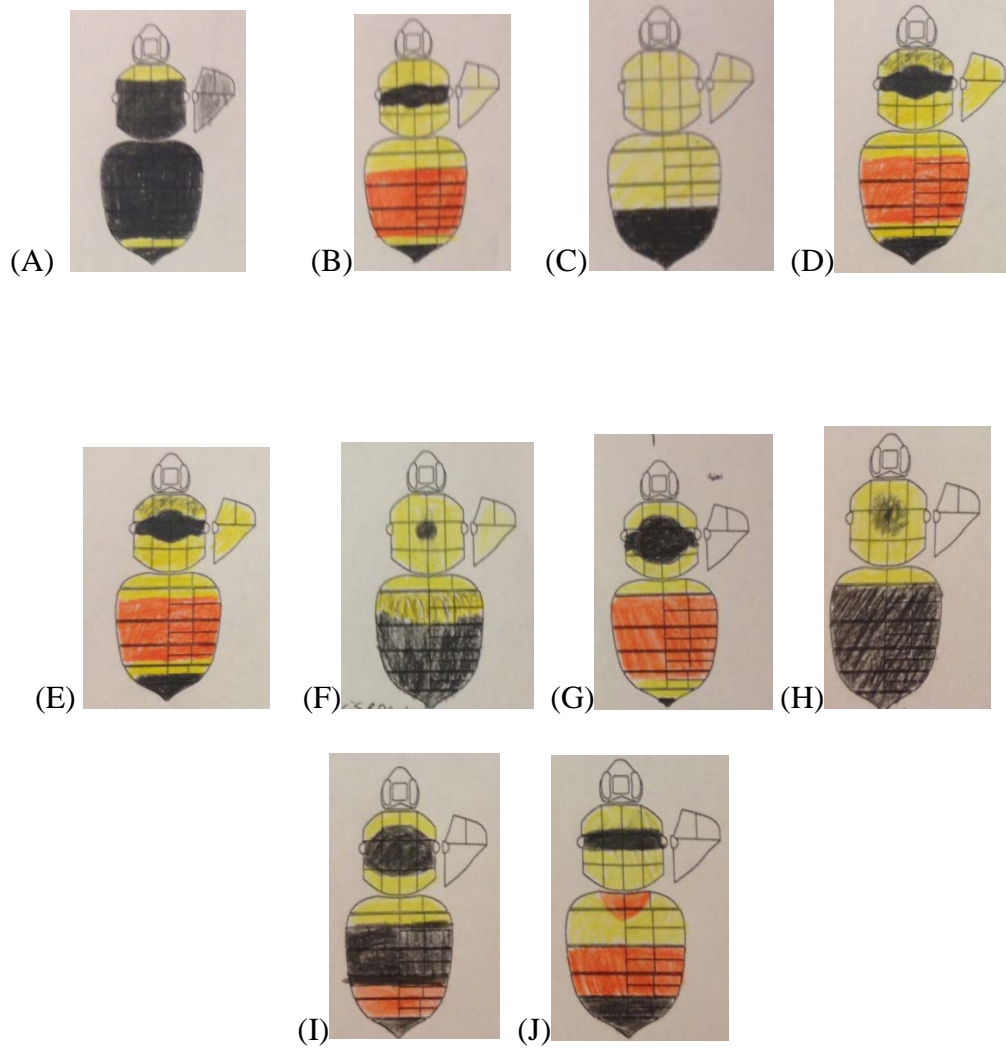
Bee	Temperature at 240 seconds	Starting Temperature	Size	Black in Thorax	Black in Abdomen	Pile length	Pile density (Thorax)	Pile density (Abdomen)	Trial
Huntii Queen	77.2	70.3	4.4	26.67%	5.26%	0.95	62	57	1
impatiens 1	77.5	70.3	3.5	15%	89.47%	0.85	49	42	1
impatiens 2	77.6	70.3	3.3	15%	89.47%	1	56	66	1
Perplexus 1	77	70.3	3.4	0%	45.21%	0.9	36	49	1
Perplexus 2	75.7	70.3	2.8	0%	45.21%	0.8	43	52	1
Griseocollis	77.3	70.3	3.6	5.83%	71.05%	0.6	69.00	59.00	1
Huntii	77.6	70.3	2.4	26.67%	5.26%	0.95	24.00	46.00	1
Melanopygus	78	70.3	3.8	31.67%	15.79%	0.65	26.00	43.00	1
Bimac 1	77.1	70.3	3.6	11.67%	81.47%	0.8	29.00	40.00	1
Bimac 2	76.4	70.3	3.1	11.67%	81.47%	0.85	27.00	41.00	1
Bimac 3	76.5	70.3	3.2	11.67%	81.47%	0.9	32.00	43.00	1
Bimac 4	76.6	70.3	3.1	11.67%	81.47%	0.95	29.00	37.00	1
Bimac 5	75.7	70.3	3.5	11.67%	81.47%	0.9	56.00	68.00	1
Huntii Queen 1	77.9	71.5	4.9	26.67%	5.26%	0.9	64.00	72.00	2
Huntii Queen 2	76.6	71.5	4.7	26.67%	5.26%	0.65	69.00	76.00	2
Huntii 1	79.2	71.5	3.1	26.67%	5.26%	0.6	35.00	39.00	2
Huntii 2	79.6	71.5	2.5	26.67%	5.26%	0.6	32.00	34.00	2
Huntii 3	78.5	71.5	2.8	26.67%	5.26%	0.75	25.00	32.00	2
Perplexus	78	71.5	4.1	0%	45.21%	0.9	49.00	47.00	2
Bimac 1	76.2	71.5	2.9	11.67%	81.47%	0.95	29.00	31.00	2
Bimac 2	78.3	71.5	3.6	11.67%	81.47%	0.9	32.00	36.00	2
Bimac 3	73.9	71.5	2.8	11.67%	81.47%	1.05	27.00	29.00	2
Bimac 4	78	71.5	2.8	11.67%	81.47%	0.69	33.00	38.00	2
Bimac 5	76.7	71.5	3.1	11.67%	81.47%	0.85	32.00	45.00	2
Bimac 6	75.2	71.5	3.4	11.67%	81.47%	1.1	32.00	44.00	2

Bimac 7	75.9	71.5	3.1	11.67%	81.47%	1	29.00	36.00	2
Bimac Queen	75.6	69	4.8	11.67%	81.47%	1.3	67.00	73.00	3
Bimac 1	77.9	69	3.2	11.67%	81.47%	1	33.00	35.00	3
Bimac 2	76.2	69	3	11.67%	81.47%	0.95	32.00	37.00	3
Bimac 3	77.1	69	2.9	11.67%	81.47%	0.9	31.00	36.00	3
Bimac 4	76.1	69	2.6	11.67%	81.47%	0.8	28.00	30.00	3
Bimac 5	75.5	69	2.6	11.67%	81.47%	0.95	28.00	34.00	3
Bimac 6	76.1	69	2.8	11.67%	81.47%	0.8	29.00	41.00	3
Griseocollis 1	74.7	69	3.7	5.83%	71.05%	0.55	64.00	71.00	3
Griseocollis 2	76.1	69	3.4	5.83%	71.05%	0.8	63.00	65.00	3
Huntii 1	79	69	3	26.67%	5.26%	0.75	28.00	34.00	3
Huntii 2	78.5	69	2.9	26.67%	5.26%	0.73	31.00	32.00	3
Impatiens	75.7	69	3.5	15%	89.47%	0.85	34.00	29.00	3
Perplexus	75.6	69	3.4	0%	45.21%	1.07	29.00	31.00	3
Huntii Queen 1	84.7	67.6	4.9	26.67%	5.26%	1.15	69.00	77.00	4
Huntii Queen 2	84.7	67.6	4.7	26.67%	5.26%	1	62.00	73.00	4
Huntii Queen 3	82	67.6	4.8	26.67%	5.26%	0.95	66.00	74.00	4
Huntii Queen 4	82.2	67.6	4.9	26.67%	5.26%	0.79	69.00	80.00	4
Bimac 1	84.8	67.6	3.6	11.67%	81.47%	0.65	61.00	55.00	4
Bimac 2	83.6	67.6	3.5	11.67%	81.47%	0.62	56.00	59.00	4
Bimac 3	82.8	67.6	3.6	11.67%	81.47%	0.96	59.00	62.00	4
Ternarius 1	86.1	67.6	2.6	45%	0.53%	0.7	43.00	35.00	4
Ternarius 2	83.8	67.6	3.1	45%	0.53%	0.7	60.00	57.00	4
Ternarius 3	84.5	67.6	3	45%	0.53%	0.65	58.00	50.00	4
Ternarius 4	84.7	67.6	2.8	45%	0.53%	0.7	46.00	32.00	4
Perplexus	85.5	67.6	3.4	0%	45.21%	0.7	67.00	78.00	4
Impatiens	84.9	67.6	3.9	15%	89.47%	0.8	58.00	54.00	4
Bimac 1	75.9	70.3	3.2	11.67%	81.47%	1.14	43.00	44.00	5
Bimac 2	75.5	70.3	3.3	11.67%	81.47%	0.9	46.00	49.00	5
Bimac 3	75.5	70.3	3	11.67%	81.47%	1.05	41.00	33.00	5
Bimac 4	76	70.3	3.2	11.67%	81.47%	1.1	44.00	45.00	5
Bimac 5	75.1	70.3	3.5	11.67%	81.47%	1.16	52.00	56.00	5
Bimac 6	75.2	70.3	3.9	11.67%	81.47%	0.7	54.00	58.00	5
Perplexus 1	75.7	70.3	3.1	0%	45.21%	0.85	42.00	36.00	5
Perplexus 2	74.9	70.3	3.6	0%	45.21%	1.1	52.00	53.00	5
Perplexus 3	74.2	70.3	3.7	0%	45.21%	0.9	57.00	63.00	5
Huntii Queen 1	75.3	70.3	4.9	26.67%	5.26%	1	72.00	74.00	5
Huntii Queen 2	75.3	70.3	4.8	26.67%	5.26%	1.15	69.00	70.00	5
Griseocollis 1	75.8	70.3	3.4	5.83%	71.05%	0.9	52.00	54.00	5
Griseocollis 2	74.4	70.3	3.6	5.83%	71.05%	0.85	62.00	57.00	5

Centralis 1	81.7	72.4	3.8	20%	26.32%	1.55	52.00	56.00	6
Centralis 2	79.9	72.4	2.9	20%	26.32%	1.25	46.00	48.00	6
Centralis 3	80.2	72.4	3.5	20%	26.32%	1.15	49.00	51.00	6
Centralis 4	79.4	72.4	3.1	20%	26.32%	1.25	48.00	52.00	6
Centralis 5	80.2	72.4	3.5	20%	26.32%	1.5	49.00	52.00	6
Centralis 6	80	72.4	3.9	20%	26.32%	1.05	54.00	55.00	6
Mixtus 1	83.3	72.4	2.9	61.67%	52.63%	1.3	26.00	24.00	6
Mixtus 2	82.6	72.4	3.4	61.67%	52.63%	1.05	32.00	27.00	6
Mixtus 3	79.6	72.4	3	61.67%	52.63%	1.07	29.00	28.00	6
Mixtus 4	82.6	72.4	2.8	61.67%	52.63%	1.3	24.00	19.00	6
Mixtus 5	79.9	72.4	3.2	61.67%	52.63%	1.45	31.00	29.00	6
Impatiens Queen 1	78.9	72.4	5.6	15%	89.47%	1.8	64.00	67.00	6
Impatiens Queen 2	77.7	72.4	5.4	15%	89.47%	1.55	61.00	63.00	6
Bimac 1	77	67.7	3.1	11.67%	81.47%	0.85	43.00	47.00	7
Bimac 2	78.7	67.7	3	11.67%	81.47%	0.7	39.00	42.00	7
Impatiens Queen 1	79.4	67.7	4.8	15%	89.47%	1.2	54.00	56.00	7
Impatiens Queen 2	78.4	67.7	5.4	15%	89.47%	1.2	57.00	58.00	7
Perplexus	78.1	67.7	2.9	0%	45.21%	0.75	52.00	55.00	7
Vosnesenskii 1	82.7	67.7	3.2	83.33%	90%	0.75	29.00	33.00	7
Vosnesenskii 2	80.7	67.7	2.7	83.33%	90%	1	28.00	27.00	7
Vosnesenskii 3	80.5	67.7	3.2	83.33%	90%	1.2	32.00	35.00	7
Vosnesenskii 4	79.8	67.7	2.9	83.33%	90%	1.1	29.00	31.00	7
impatiens 1	83.1	67.7	2.4	15%	89.47%	1	22.00	19.00	7
Impatiens 2	81.3	67.7	2.9	15%	89.47%	0.85	24.00	20.00	7
impatiens 3	78.1	67.7	3.4	15%	89.47%	1.15	32.00	32.00	7
impatiens 4	78.6	67.7	3.6	15%	89.47%	1.08	34.00	37.00	7
Bimac 1	85.2	73.4	3.6	11.67%	81.47%	0.9	40.00	42.00	8
Bimac 2	84.3	73.4	3.5	11.67%	81.47%	1.05	37.00	44.00	8
Bimac 3	85.9	73.4	3.8	11.67%	81.47%	1.23	42.00	38.00	8
Vosnesenskii 1	84.5	73.4	3.3	83.33%	90%	0.8	32.00	33.00	8
Vosnesenskii 2	85.7	73.4	3.5	83.33%	90%	0.75	34.00	38.00	8
Vosnesenskii 3	84.8	73.4	3.2	83.33%	90%	1	29.00	34.00	8
Vosnesenskii 4	85.6	73.4	3.1	83.33%	90%	0.9	27	33	8
Vosnesenskii 5	84.8	73.4	2.7	83.33%	90%	1.05	26	29	8
Vosnesenskii 6	85	73.4	2.8	83.33%	90%	1	27	30	8
Vosnesenskii 7	83.2	73.4	3.1	83.33%	90%	1.25	28	31	8
Vosnesenskii 8	84	73.4	2.9	83.33%	90%	1.15	27	31	8
Vosnesenskii 9	83.6	73.4	3.1	83.33%	90%	1.1	27	32	8
Perplexus	84.1	73.4	3.4	0%	45.21%	0.75	43	36	8
Griseocollis 1	91.2	82.2	3.8	5.83%	71.05%	0.75	64.00	69.00	9

Griseocollis 2	90	82.2	3.3	5.83%	71.05%	0.65	59.00	65.00	9
Griseocollis 3	89.5	82.2	3.5	5.83%	71.05%	0.8	63.00	67.00	9
Bimac 1	91.1	82.2	3.3	11.67%	81.47%	1.3	32.00	38.00	9
Bimac 2	88.7	82.2	3.5	11.67%	81.47%	1.25	34.00	37.00	9
Bimac 3	86.8	82.2	3	11.67%	81.47%	1.45	28.00	31.00	9
Bimac 4	86.5	82.2	3.2	11.67%	81.47%	1.05	29.00	36.00	9
Ternarius 1	89.8	82.2	2.6	45%	0.53%	0.65	27	32	9
Ternarius 2	88.2	82.2	2.9	45%	0.53%	0.9	31	33	9
Impatiens Queen 1	89.9	82.2	5.2	15%	89.47%	1.78	68	71	9
Impatiens Queen 2	87.9	82.2	5.3	15%	89.47%	1.88	72	73	9
Impatiens Queen 3	87.2	82.2	5.1	15%	89.47%	1.85	66	68	9
Impatiens Queen 4	86.3	82.2	5.6	15%	89.47%	1.43	73	76	9
Perplexus 1	81.5	70.8	3	0%	45.21%	0.75	34	19	10
Huntii Queen 1	82.3	70.8	4.6	26.67%	5.26%	0.9	69.00	76.00	10
Huntii Queen 2	80.3	70.8	4.6	26.67%	5.26%	1.05	67.00	71.00	10
Huntii Queen 3	80.4	70.8	4.5	26.67%	5.26%	1.5	64.00	67.00	10
Huntii Queen 4	82.5	70.8	4.7	26.67%	5.26%	1.25	71.00	73.00	10
Huntii Queen 5	83	70.8	4.8	26.67%	5.26%	1.6	73.00	75.00	10
Vosnesenskii 1	78.5	70.8	2.9	83.33%	90%	1.5	25.00	31.00	10
Vosnesenskii 2	82	70.8	3.1	83.33%	90%	1	26.00	32.00	10
Vosnesenskii 3	80.6	70.8	2.2	83.33%	90%	1.35	22.00	21.00	10
Vosnesenskii 4	76.9	70.8	3.2	83.33%	90%	1.4	28.00	35.00	10
Vosnesenskii 5	80	70.8	2.5	83.33%	90%	1.15	24	28	10
Vosnesenskii 6	82	70.8	2.6	83.33%	90%	1.55	24	29	10
Vosnesenskii 7	81.7	70.8	3.2	83.33%	90%	1.5	29.00	33.00	10

Color Forms of Each Bee Species



(A) *B. vosnesenskii*, (B) *B. huntii*, (C) *B. perplexus*, (D) *B. melanopygus*, (E) *B. bimaculatus*,
 (F) *B. griseocolis*, (G) *B. ternarius*, (H) *B. impatiens*, (I) *B. mixtus*, (J) *B. centralis*

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Religion and Sexual Orientation: Effects on Mental Health

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Abstract

Members of the Lesbian, gay, bisexual, and transgender (LGBT) community are at a higher risk for many mental and physical illnesses compared to heterosexual individuals. This pattern may be, in part, due to social stigma from the broader community and may be particularly acute when stigma is expressed by communities that LGBT individuals also identify with. This research study examined the impact of self-reported religiosity on anxiety levels among the LGBT community and a heterosexual comparison group. We looked to see if LGBT community members expressed higher levels of anxiety with increases in religiosity, particularly if they belong to groups with a generally negative attitude toward homosexuality. The study involved a total of 143 participants.

Introduction

Sexual orientation has become a very popular, and sometimes controversial, topic of discussion in society. This may be due to traditional norms that disapproved of and discouraged questions of sexuality. However, recent social mores have become more accepting of variations in sexual orientation. Given this growing level of conversation, there has been a large amount of research examining the lesbian, gay, bisexual, and transgender (LGBT) community regarding their mental and physical health.

Lesbian, gay, and bisexual adults are at a higher risk for poorer mental and physical health than heterosexual individuals (Institute of Medicine, 2011). Typically, sexual minorities report more depression, anxiety, acute physical complaints, limitations of activities, tension, and asthma than heterosexuals (Cochron & Mays, 2007; Conron, Mimiaga & Landers, 2010; King et al., 2008; Sandfort, Bakker, Schellens & Vanwesenbeeck, 2009). Previous research has also shown that sexual minority individuals are more at risk for other health disparities, such as cancer, cardiovascular disease, high cholesterol, asthma, and other health issues. This pattern may result from the added stress associated with being a minority in society (Lick, Durso, & Johnson, 2013). Many of these symptoms reflect idiosyncratic stressors that sexual minority individuals

encounter due to social stigmatization (Meyer, 2003). Meyer suggested that these stressors include heterosexism, stigma consciousness, sexual orientation concealment, and internalized homophobia. Internalized homophobia, for example, is the internalization of stigma related to one's sexual orientation and negative perception of themselves. Based on a recent meta-analysis, internalized homophobia was, in turn, associated with anxiety and depression (Newcomb & Mustanski, 2010).

Gay and bisexual men particularly are at a higher risk for poorer mental and physical health as a result of their sexual orientation. Gay and bisexual men are disproportionately diagnosed with mental health concerns including mood and anxiety disorders as well as associated behavioral comorbidity, such as substance use problems and/or HIV risk behavior compared to heterosexual men (Cochran et al., 2003; Mills et al., 2004).

Recent work has examined the effects of religion on the lives of individuals in the LGBT community. Some religions practice discrimination against lesbian, gay, and bisexual individuals, preach against same sex attractions, or cast LGB individuals violating norms for good and acceptable behavior. These negative messages may compromise the mental health of LGB individuals in general (Sowe, Brown & Taylor, 2014). However, the impact may be particularly acute for individuals who view religion as an essential aspect of their lives, despite the religious condemnation many gay and lesbian women face, (Davies, 2000). Religion is very essential to a large number of people and their lives as well as the way they perceive themselves. Religion is typically associated with both social and health benefits such as improved mental and physical health, increased life satisfaction, and higher quality of life (Ellison and Levin 1998; Ellison, 1993; Levin, Chatters, & Taylor, 1995). Furthermore, church-based health promotion programs and interventions have proven to reduce smoking behaviors and promote physical activity (Campbell, Hudson, Resnicow, Blakeney, Paxton & Baskin, 2007). Such positivity is also evident among youth. Religious adolescents report lower rates of risky behaviors, decreased likelihood of substance use and delinquency as well as fewer mental health issues (Smith, 2005). Unfortunately, such positive contributions and outcomes may not be available to lesbian, gay, bisexual, or transgender individuals. The social environment as well as the worldview and ideologies of many religious organizations are marked by negative beliefs about sexual minorities, leading to discrimination against and maltreatment of individuals as a result of their sexuality (Altman, Aggleton, Williams, Kong, Reddy, Harrad, Reis, Parker, 2012). Thus, many LGBT individuals who are highly religious can possibly experience some level of anxiety, depression, low self-esteem, and/or self-worth, especially if they are involved in a religion that does not approve of the LGBT community or lifestyle.

The goal of the current study is to examine patterns of anxiety among individuals that vary in sexual orientation and level of homosexual attractions as a function of level of religiosity. I hypothesize that in general, individuals who self-identify as LGBT community or who feel homosexual attractions will have higher social anxiety than heterosexual individuals. I also hypothesize that individuals that self-identify as members of the LGBT community or who feel homosexual attractions that are highly religious will have higher anxiety than highly religious

heterosexual individuals. I also predict that homosexual men will have higher anxiety than homosexual women.

Methods

Participants and procedures

Enrollment to participate in this research study began June 10, 2016 using various forms of recruitment strategies: 9 participants were from Amazon's Mechanical Turk, 199 participants were recruited through community outreach and listservs, including groups focused on the Lesbian Gay Bisexual Transgender community listservs. Mechanical Turk is a marketplace through Amazon that requires human intelligence. It gives businesses access to workforce and simultaneously giving workers a selection of numerous tasks to complete at their convenience. Each participant from Mechanical Turk received \$0.10 for completing the questionnaires.

In order to be eligible for participating in this research study, participants were required to be at least 18 years of age. Participants could be heterosexual, lesbian, gay, transgender or bisexual.

Questionnaires were presented on line via Qualtrics (Provo, Utah). Consent was provided using an online form prior to presentation of the questionnaires. Procedures were reviewed and approved by the Institutional Review Board at the Pennsylvania State University.

Measures

Demographics: Participants were asked questions regarding their demographics. They were asked their age, biological sex at birth (male or female), gender identity (male or female), race (Hispanic, Asian/Pacific Islander, White, Native American, or other), and religious affiliation (Baptist, Catholic, Lutheran, Presbyterian, Methodist, Non-Denominational Christian, Jewish, Islamic, Buddhist, Hindu, None, or other).

Anxiety: The Beck Anxiety Inventory (Beck & Steer, 1993) was used to measure level of anxiety. Participants were assessed on 21 items associated with anxiety symptoms (e.g. unable to relax, nervous, unsteady, etc) using a 4-point Likert scale: Not at all (0), mildly but it didn't bother me much (1), moderately-it wasn't pleasant at times (2), or severely-it bothered me a lot (3). Scores on the BAI can range from 0 to 63 after adding up all the scores for each of the 21 questions (0-7 = minimal level of anxiety, 8-15= mild anxiety, 16-25=moderate anxiety, and 26-63= severe anxiety).

The 40-item State Trait Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) was also used to assess the individuals' level of anxiety during the current moment (state) as well as in general (trait). (e.g. "I feel secure", "I feel upset", "I feel nervous and restless", "I worry too much over something that doesn't really matter", etc.). Participants respond using a 4-point Likert scale: Almost never, Sometimes, Often, or Almost Always. Scores on the STAI have two separate measurements, one is state and the other is the trait. Scoring for both of these

measurements is taken by calculating the mean of all the state items and calculating the mean for the trait items.

Depression: The levels of depressive symptoms were assessed with the Beck Depression Inventory (Beck, Steer, Brown, 1996). The BDI is a 21-item, self-report scale, which assesses the severity of depressive symptomatology. Participants were able to select the statement(s) that best fit the way they feel using a scale of 0 to 3. For example, “I do not feel sad” (0), “I feel sad” (1), “I am sad all the time and I can’t snap out of it” (2), and/or “I am so sad or unhappy that I can’t stand it” (3). Scores may range from 0 to 63 (0-10= these ups and downs are considered normal, 11-16= mild mood disturbance, 17-20= borderline clinical depression, 21-30= moderate depression, 31-40= severe depression, and over 40= extreme depression).

Religiosity and Spirituality: The Religiosity and Spirituality Scale for Youth (Hernandez, 2011) was administered to measure participants’ religiosity and spirituality level. The 37 items on this scale referred to religious activity and participants rate the items using the following 4-point scale: 0=Never, 1=Sometimes, 2=Mostly, 3=Always. Some items on the Religiosity and Spirituality Scale for Youth include, “I pray in public, I attend prayer groups, I have a close relationship with God” etc. Participants were also asked what religion and denomination they were affiliated with (Baptist, Catholic, Lutheran, Presbyterian, Methodist, Non-Denominational Christian, Jewish, Islamic, Buddhist, Hindu, None, or other). Participants reported how often they pray, attend church, mosque, temple, and/or youth group, and their religion and church’s stance on the LGBT community and gay marriage.

Sexual Orientation: The Sell Assessment of Sexual Orientation (Sell, 1996) was used to gather information on each participant’s sexual orientation. The first 6 items assessed how often and intensely participants are sexually attracted to men and/or women. The next 4 items asked participants about their sexual (bodily) contact with other men and/or women. The last 2 items asked participants about their sexual orientation identity. There are 4 different scores on the SASO; homosexuality, heterosexuality, bisexuality, and asexuality. Homosexuality, heterosexuality, & bisexuality are all on a 4-point Likert scale. Asexuality scoring is either asexual or not at all asexual.

Analytic Plan

Initial analyses examined the demographic characteristics of the final sample. Importantly, we looked to see that the sample had adequate representation of the core factors of interest, namely sexual orientation and religiosity. We then turned to examine the core hypotheses laid out in the study.

First, using continuous variables, we examined zero-order correlations between levels of religiosity, levels of homosexual attraction, and anxiety, as well as demographic factors, such as age, gender, and ethnicity. Analyses were completed using categorical between-subjects measures of sex and sexual orientation within an initial ANOVA analysis to examine levels of anxiety. The follow up ANCOVA used religiosity to examine the potential impact on anxiety.

Finally, we examined the inter-relations between our measures using a PROCESS model (Preacher et al., 2007) using sexual orientation, gender, and religiosity, to examine the direct and conditional effects on anxiety.

Analyses were then repeated using a continuous measure of homosexual attraction as our predictor variable.

Results

We had a sample of 208 participants in data collection. Of these, we removed 42 participants who did not complete the study. Our final sample consisted of a total of 163 participants, 26% male, 74% female and average age of 29 (SD=11.26). There were 24 who identified as Asian/Pacific Islander, 9 were Hispanic, 109 were Caucasian, 1 were Native American, and 22 identified as other.

Overall, the mean religiosity score was 71.63 (SD=28.8). Religiosity did not vary as a function of denomination. In addition, levels of religiosity did not differ significantly as a function of age, gender, and race, $p's > 0.08$.

In addition, we note the score derived from the Sell Assessment of Sexual Orientation. Participants disclosed the extent to which they felt homosexual, heterosexual, or bisexual (i.e. not at all, slightly, moderately, etc.). Participants also disclosed their sexual contact between a male or female within the past year as well as the amount of sexual attractions they had for a male or female.

Within the sample, 76 (28 male) participants self-identified as homosexual and 93 self-identified as heterosexual (16 male). The distribution was significantly skewed, $\chi^2(1,169) = 0.38$, $p=0.004$, based on the large percentage of female participants and the variation in sexual orientation within males and females. The distribution of participants in the sexual orientation groups did not differ significantly as a function of age and race, $p's > 0.10$. As expected, level of homosexual attraction was significantly higher in the homosexual group (2.12 vs. 0.47), $t(162) = 11.73$, $p < 0.001$. Although there were proportionately more homosexual men in the sample than homosexual women, the interaction between sex and sexual orientation when examining homosexual attraction levels only approached significance, $F(1,165) = 2.82$, $p = .10$.

The initial ANOVA examined the impact of sexual orientation and sex on levels of religiosity. The findings suggest no main effect of sex, ($p=0.99$), and no sex by orientation interaction, ($p=0.86$). However, there was, at trend, the suggestion that individuals who self-identify as homosexual were less religious (66.3 vs. 75.1), $F(1,165) = 2.89$, $p = .09$.

Initial t-tests suggested that homosexual participants were higher in anxiety than heterosexual participants, $t(149) = 1.96$, $p = 0.05$ (6.75 vs. 4.34). However, this relation was no longer significant when sex was added as a second predictor, $F(1,147) = 2.30$, $p = 0.13$. The interaction between sexual orientation and sex was not significant, $F(1,147) = 0.21$, $p = 0.65$. When examining level of anxiety as a categorical measure (healthy, sub-clinical, and clinical), again

homosexual participants trended toward greater anxiety and impairment, $\chi^2(2,151)=4.52$, $p=0.033$.

We then ran an ANCOVA, adding religiosity to the initial ANOVA analysis examining anxiety levels. Our findings indicated no main effect of religiosity, $p=0.51$, and no interactions with either sexual orientation or sex, $p's>0.31$. The correlation between religiosity and anxiety did not reach significance when examined separately for homosexual and heterosexual participants, $r's<0.15$, $p's>0.15$.

Finally, we examined a PROCESS model predicting level of anxiety as a function of sexual orientation (categorical), sex (categorical), religiosity (continuous), and each of the two-way and three-way interactions. The overall model was not significant, $F(7, 143)=1.13$, $p=0.35$. However, as reflected in our individual analyses, sexual orientation was once again significantly related to anxiety levels, $t=-1.97$, $p=0.05$. No other factors were significant, $p's>0.173$.

We then examined our initial hypotheses using a more continuous measure of sexual orientation—that is, homosexual attraction.

First, we examined the zero-order correlations between homosexual attraction, religiosity, and anxiety. There was a negative correlation of, $r(170)=-.251$, $p=.027$, between the level of homosexual attraction and religiosity. In addition, there was a significant positive correlation between level of homosexual attraction and anxiety, $r(152)=.192$, $p=.018$. There was no significant correlation between religiosity and anxiety, $r(152)=-.047$, $p=.562$.

For female participants, homosexual attraction was negatively correlated with religiosity, $r(126)=-.270$, $p=.002$. The correlation, while in the same direction, was not significant for male participants, $r(44)=-.210$, $p=.172$. Follow-up analyses found that the two correlations were not significantly different from each other, $Z=-0.353$, $p=0.72$.

For female participants, homosexual attraction was positively correlated with anxiety, $r(113)=.225$, $p=.017$. The correlation, while in the same direction, was not significant for male participants, $r(39)=.143$, $p=.385$. Follow-up analyses found that the two correlations were not significantly different from each other, $Z=0.442$, $p=0.66$. Religiosity did not correlate with anxiety for either women, $r(113)=-.011$, $p=.907$, or men $r(39)=-.188$, $p=.253$.

Our overall ANCOVA examined the impact of homosexual attraction levels, sex, and religiosity on levels of anxiety. None of the predictors reached significance when examined together in a single model, $F's < 0.850$, $p's>0.358$.

Finally, we examined a PROCESS model predicting level of anxiety as a function of homosexual attraction (continuous), sex (categorical), religiosity (continuous), and each of the two-way and three-way interactions. The overall model was not significant, $F(7, 144)=1.37$, $p=0.22$. However, as reflected in our individual analyses, homosexual attraction was once again significantly related to anxiety levels, $t=2.63$, $p=0.010$. No other factors were significant, $p's>0.212$.

Discussion

This research study examined the anxiety and depressive levels among individuals self-identifying sexual orientation as a function of religiosity. We also looked at the impact of sex on the interrelations between sexual orientation, religiosity, and anxiety.

Our examination took both a categorical (sexual orientation) and continuous (homosexual attraction) approach in hopes of pulling apart potential variations in anxiety and religiosity. When examining sexual orientation, it appears that homosexual individuals are both less religious and higher in anxiety. These findings are in line with the initial hypotheses. They are also in line with previous studies indicating that homosexual individuals report more depression and anxiety (Cochron & Mays, 2007; Conron, Mimiaga & Landers, 2010; King et al., 2008; Sandfort, Bakker, Schellens & Vanwesenbeeck, 2009).

However, when examining the factors together we did not find that religiosity or sex influenced the relation between sexual orientation and anxiety. As such, our higher order hypotheses were not supported.

Our analyses with sexual attraction paralleled the categorical findings, as level of homosexual attraction was negatively correlated with religiosity and positively correlated with anxiety. There was some indication that these relations were stronger for women. Again, there were no significant interactions when examining sexual attraction, religiosity, and sex together to predict anxiety.

A number of conclusions can be drawn from this preliminary study. First, individuals who self-identified as homosexual or had more homosexual attractions were less religious. It may be that they were therefore less conflicted regarding the clash between sexual orientation and religion.

This study also found that the more homosexual attractions women have, the more anxious feelings they have. For homosexual men, there was no significant relationship between their gender and their levels of anxiety. This finding was the opposite of what we hypothesized prior to completing this research study. However, this finding may be the result of the large gender imbalance in our sample size; as the make-up was 74% female and 26% male.

This study produces support and evidence for further research regarding the effects of religion and sexual orientation on mental health. However, there are limitations to our study. There was a large gender imbalance in our final sample, with 74% female and 26% male participation. A larger, targeted recruitment procedure may have resulted in a larger sample size with a smaller gender imbalance. We also had a small sample size of 165 participants. In order for our results to accurately generalize to a specific population, a larger sample is needed. A large sample size could have also given us a better distribution of membership in specific religious denominations. This could be beneficial to our study by allowing us to have a diverse group of religions that accept the LGBT community and those that do not accept the LGBT community.

This study underlines several directions for future research. Our study focused on the levels of religiosity and spirituality of each participant. Additional research is needed to explore the anxiety and/or depressive levels within specific denominations varying in levels of acceptance for the LGBT community. For example, one could explore variation in anxiety levels of homosexual individuals who are a part of a religion that accepts sexual minorities versus anxiety levels among individuals who are a part of a denomination that does not accept sexual minorities. This analysis may be able to help us understand whether condemnation and discrimination in religious groups has the hypothesized mechanistic effect on mental health among members of the LGBT community. Other research could also benefit from having a larger sample size in order to make findings more generalizable for and in order to have proportionate groups to compare (i.e. women vs. men, homosexuals vs. heterosexuals). Expanding this research in these ways can help us understand minorities' mental health in order to enhance their mental health if needed. Further research can also contribute to better educating society as a whole about sexual minorities and their health as a means of creating less judgement and condemnation towards sexual minorities.

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Language Experience, Dialect Use and their Effect on Language Comprehension

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Abstract

This study focuses on dialect and its impact on language comprehension. Specifically, we investigate the Central/Western Pennsylvania dialect and how dialect use influences language comprehension of the “needs” construction, as in “The car needs washed,” instead of “The car needs to be washed.” The “needs” construction is spoken in Central/Western Pennsylvania, as well as other states in the Midwest, like Illinois, Missouri, and Iowa. The present study found that regardless of familiarity with the “needs” construction, people had difficulty reading the “needs” construction, but that the people unfamiliar with the “needs” construction adapted to the novel construction rapidly, whereas those already familiar with the “needs” construction did not. The results of this study have important implications for research showing that prior linguistic experience influences the difficulty of real-time language comprehension (e.g., Kaschak & Glenberg, 2004; Fine et al., 2013,) and highlights why dialect use should be considered when dealing with language comprehension.

Introduction

People are able to adapt to different grammatical and lexical changes over time when thrown into a new language environment. There are many different linguistic environments, even in the same state, in which people speak differently from county to county. When a person moves to a new area with a different dialect, how well does he or she adapt? Language comprehension and experience go hand and hand. Exposure to different dialects is a type of language experience that may influence language comprehension. Dialect and non-standard forms of language vary over time and place. Exposure to different dialects and non-standard forms shapes the way a person may think about language and what sounds standard to them. Therefore, an important question to ask is how do dialectal differences affect the comprehension of standard American English or any other dialect?

There are varying dialectal regions in the state of Pennsylvania, with Eastern Pennsylvania commonly classified as a separate dialect region from Central and Western Pennsylvania (Murray, Frazer, & Simon, 1996). One grammatical construction that is widespread in the Central/Western portion of Pennsylvania is the “needs” construction. For example, a person from Central Pennsylvania may say, *The carpet needs vacuumed before the guests arrive*, instead of saying *The carpet needs to be vacuumed before the guests arrive*. Does this person realize that he or she is saying something that is considered ungrammatical by speakers outside of his or her dialectal region? This study will address a person’s experience

with the Central Pennsylvania dialect and its impact on the comprehension of Standard American English.

Language Comprehension of Novel/ Less Frequent Constructions

Prior linguistic experience can have an impact on the relative difficulty of comprehending different syntactic structures. Wells, Christiansen, Race, Acheson, and MacDonald (2009) conducted a study to investigate how people comprehend subject relative clause sentences, example (1) below, compared to object relative clause sentences, example (2) below. In subject relative clauses, the subject of the main sentence is the grammatical subject in the relative clause. In object relative clauses, the subject of the main sentence is the direct object in the relative clause. Subject relative clauses are easier to comprehend than object relatives because they are similar to common simple transitive sentences, as in example (3) below, and they are more common in English overall.

1. Subject relative clause: The reporter that attacked the senator admitted the error.
2. Object relative clause: The reporter that the senator attacked admitted the error.
3. Simple Transitive Sentence: I rode the bicycle up the hill.

Wells et al. (2009) predicted that structures that share word order similarities with common simple transitive sentences, and are more frequent overall in the language, like subject relative clauses, would benefit less from additional experience than structures that do not share word order similarities with common simple transitive sentences and are less frequent overall in the language, like object relative clauses. Increased experience with object relative clauses would allow for better comprehension of this less-frequent syntactic structure. This is indeed what Wells et al. found, leading them to conclude that language experience with certain relative clauses shapes the way comprehenders adapt to linguistic input.

Working memory can also influence syntactic processing. According to Long and Prat (2008), there are different working memory limitations which, may influence the ability of a person to comprehend language. In the distributional-learning model, knowledge and practice influences language comprehension. Reading span differences have an impact on how people process syntactic ambiguities, like the main-verb/reduced relative ambiguity, *The salad tossed for the party looked delicious*. At the point readers encounter the main verb (e.g., *tossed*), these sentence types can be open to more than one interpretation. Low-span readers' limited knowledge about the sentence ambiguity hindered them from processing the ambiguity at a faster rate. At the same time, Long and Prat show that repeated exposure to these structures can minimize processing differences between high-span readers and low-span readers. More exposure to a novel or less frequent syntactic construction allows for greater comprehension no matter the working memory capacity of the individual, highlighting that language comprehension of syntactic structures also depends on the characteristics of the reader and the complexity of the sentence structure.

Language experience, input, and comprehension eventually can influence language production. The production of a certain utterance gives insight into how an utterance was comprehended by the speaker. MacDonald (2013) emphasizes the Production-Distribution-

Comprehension (PDC) approach in learning how language is processed with regard to word order choices and ease of language planning, thereby proposing a close connection between the choices speakers make in language production and how different structures are comprehended in real time. MacDonald found that the linguistic signals which, unfold over time, always have ambiguity, namely vagueness of meaning in language. To mitigate these ambiguities, comprehenders tend to take what they have learned from various inputs, past experience and implicit utterance choices to understand what needs to be processed. Dialect is a form of language production that can have varying linguistic ambiguities which, a comprehender has to take into account when planning utterances, encountering new dialectal variants, and comprehending linguistic input.

Language Adaptation to Novel/Less Frequent Constructions

New environments offer new linguistic forms of language. Comprehenders may develop expectations about these new environments based on their previous linguistic experience. Fine, Jaeger, Farmer, and Qian (2013) hypothesized that comprehenders will implicitly learn a new or less-frequent syntactic structure when exposure to this structure is increased in the linguistic environment, leading to reduced processing costs. Comprehenders are able to adapt to syntactic constructions through implicit learning of the expectations in a new linguistic environment. Fine et al. (2013) found that comprehenders continuously adapt their syntactic expectations to the statistics of novel linguistic environments, and that the resulting environment-specific expectations can overturn expectations based on previous experience. With various complex linguistic environments, comprehenders adapt to these environments over time throughout their lifespan.

Structural facilitation is the increased preference for the grammatical structure of a recently encountered sentence. In a study by Luka and Barsalou (2005), participants first read a series of unrelated ungrammatical sentences presented individually (reading task). Afterwards, the participants rated sentences (rating task) which, were structurally similar to the ungrammatical sentences they had been exposed to in the reading task as more grammatically acceptable. Luka and Barsalou hypothesized this was based on prior exposure to the novel ungrammatical sentences in the reading task. Structural facilitation is a type of implicit learning. Exposure to a novel construction helps an individual to grammatically accept similar syntactic structures in the future, even when they are actually ungrammatical or only marginally grammatical. Language adaption in the context of non-standard dialects may work the same way, in the sense that a novel dialect becomes more acceptable as exposure to that dialect increases.

Priming: Insights into Adaptation

Similar to the above notion Luka and Barsalou (2005) proposed that exposure to a new syntactic construction leads to grammatical acceptability over time, Kaschak, Loney and Borreggine (2006) found that recent experience with a particular syntactic construction affects the strength of structural priming. Structural priming occurs when a speaker repeats the same syntactic constructions that he or she has recently heard or produced. The degree of language experience with a particular construction modulates the amount of subsequent priming. Connecting this notion to the research question of how dialectal differences impacts language

processing, an individual that has a particular dialect may produce different syntactic constructions more often than others because of his or her language experience.

Speakers can adapt to new constructions in an unfamiliar dialect using implicit learning and prior knowledge. Using the “needs” construction, Fraundorf and Jaeger (2016) studied how this unfamiliar syntactic structure is processed and generalized across different speakers. Implicit learning, specifically learning complex information without awareness of what is being learned, plays a critical role in the comprehension of unfamiliar syntactic constructions. Readers unfamiliar with the Central/Western Pennsylvania and Ohio dialect quickly adapted to the “needs” construction and implicitly learned to process this construction to the point that their reading time patterns on the construction, as a whole, were similar to readers who are familiar with the construction. Linguistic variability is also a factor in how speakers adapt to unfamiliar syntactic constructions. Even speakers of the same language may say things differently from each other. Fraundorf and Jaeger show that through implicit learning and adaptation of linguistic variability, a native speaker of English can rapidly adapt to a new dialect that is different from his or her own.

The comprehension of a novel construction may lead to changes in how people process familiar syntactic structures, which a comprehender already knows. In a study by Kaschak and Glenberg (2004), English native speakers in Wisconsin encountered the “needs” construction and they adapted to new linguistic input rapidly, similar to the participants in Fraundorf and Jaeger’s study (2016). The participants read the “needs” sentence, example (4) below, and a modifier sentence, example (5) below. The opening sequence of the two sentences, example (6) below, is the ambiguous portion of the sentence, which initially lead to misinterpretation of the “needs” construction. Any native speaker of English can read the ambiguous portion of the sentence and come up with his or her own completion. However, Kaschak and Glenberg (2004) found that readers, who were trained on the “needs” construction, read the modifier construction faster in a second phase of the reading task than participants, who trained on the standard version of this construction. Adaptation to the “needs” construction essentially facilitated the processing of the modifier construction. Therefore, adaptation of novel constructions with similar syntactic ambiguities leads to greater comprehension of even previously known language syntactic constructions.

4. The meal needs cooked.
5. The meal needs cooked vegetables to make it complete.
6. The meal needs cooked...

Origin of Needs Construction

Where exactly did the “needs” construction originate? According to Murray, Frazer, and Simon (1996), the “needs” construction was brought to the New World by the Scotch-Irish in the 17th and 18th centuries. It is mainly spoken in the Midland portion of the U.S. and is recognized by speakers outside of Central/Western Pennsylvania and Ohio. Through surveys conducted by Murray et al., between 1984 and 1988, participants from the states of Indiana, Illinois, Missouri, Iowa, Kansas, South Dakota and Nebraska report recognizing and even using the “needs” construction. It is also known that even though people may recognize the construction in these

areas, users and non-users of the construction co-exist in the same dialectal areas. In a study conducted by Bloomquist (2009), African-Americans in the rural and urban Lower Susquehanna Valley (LSV) area were tested to see if they had used, heard, or never used the “needs” construction before. Bloomquist (2009) found that African-Americans from both the urban and rural LSV area had equal familiarity with the “needs” construction, as compared to European-Americans from the urban and rural LSV area. Despite the African-American communities’ decreased interaction with European-Americans, they still showed increased rates of familiarity with the “needs” construction.

According to Murray et al. (1996), speakers who have grown up speaking the “needs” construction are often oblivious that they even say it. Users of the construction often incorporate it into their language so unconsciously that speakers will actually deny using the “needs” construction, then turn around and use it only moments later without realizing they have done so. Murray et al. also mentioned that teachers, who accept the construction as standard, may teach their students the construction as standard as well.

Present Study

In the present study, I will investigate how dialect, as a measure of language experience, affects how people comprehend sentences in real-time. Through collecting data from native English speakers, who grew up in Pennsylvania or Ohio, and comparing them to native English speakers from surrounding states, we can examine how language dialect and experience impacts language comprehension of the “needs” construction. This research has important implications for our understanding of syntactic adaptation, structural priming and language comprehension more generally. Thus, the present study addressed the following research questions:

- Do people who are used to the “needs” construction think that it is grammatically correct?
- Can dialect experience influence an individual’s expectations during real-time language comprehension?

Method

Participants

Participants in this study stem from previously recorded data from the spring of 2016 and the summer of 2016. All participants were recruited from the student population or surrounding university community at a large university in the northeastern United States. Participants received either course credit or nominal compensation for their participation. Twenty-nine males and sixty-nine females participated in the study. The mean age of the participants was 19 years old. The age range of the participants was between 18-57 years old. One participant was a native of Ohio. Twenty-eight participants were natives of Central/Western Pennsylvania. Thirty-three participants were natives of Eastern Pennsylvania. Thirty-six participants were natives of other surrounding states, such as Maryland, Virginia, New York and New Jersey. As described in greater detail below, half of the participants received the “needs” training, and half of the participants received the standard training.

Materials

Phase 1 (Training) of the experiment consisted of thirty-five sentences. The experiment had ten “needs” sentences, example (7) below, or ten standard sentences, example (8) below, and fifteen filler sentences, example (9) below. Phase 2 of the experiment consisted of fifty sentences. Ten sentences represented modifier sentences, such as *The ceramic tile needs washed stickers to be put on it*. There were 10 needs sentences or standard sentences, examples (7) or (8) below. The last thirty were filler sentences, example (9) below. The participants received the same types of sentences, either “needs” or standard sentences, from Phase 1 (Training) to Phase 2. (See Appendix A for a complete list of experimental items).

7. “Needs” construction: Florida oranges need peeled before they can be eaten.
8. Standard construction: Florida oranges need to be peeled before they can be eaten.
9. Filler items: The girl played with the doll while her brother played with the truck.

At the end of each sentence, participants answered a yes/no comprehension question, such as “*Are the oranges from Florida?*”

Procedure

Upon arrival, participants signed a consent form. Next, they completed a language history questionnaire asking about years of formal education, language proficiency in their native language and any foreign languages, and where they grew up. In the self-paced reading task, participants read sentences word for word on the computer. The sentences appeared in a series of dashes, and as the participants pressed the space bar, the first word of the sentence appeared. Each time the participant pressed the space bar, the next word in the sentence appeared and the prior word disappeared. After each sentence, a yes/no comprehension question appeared and participants pressed the appropriate key, Y or N, on the keyboard.

There were two different conditions of the study, one in which participants encountered only the “needs” construction, and one in which participants encountered only the standard construction. In the Training portion (Phase 1) of the experiment, there was one “needs” sentence or one standard sentence, depending on which training condition participants were assigned to, followed by two filler sentences. During Phase 2, sentences were presented in a pseudorandomized order, with no sentences with the same condition presented in a row.

After the self-paced reading task, the participants completed a task that measured their working memory. In this working memory task, the participants memorized English words on the screen as they simultaneously solved mathematical equations. The participants first saw a simple math equation on the screen with an answer, and they had to decide whether the answer provided was correct or incorrect using two keys on the keyboard labeled Y or N. Then a word appeared on the screen for 1250 milliseconds. The equations and words appeared in sets of two to six pairs, with a word after each equation. The word RECALL appeared on the screen after each set, at which point the participants had to type as many of the English words as they could remember and press the escape (ESC) key when they finished. The participants were not allowed to type the last word in the set first during the recall portion of the experiment.

Following the working memory task, participants completed an acceptability judgment task. In the acceptability judgement task, the participants were given a series of sentences, the same sentences as the self-paced reading task, and judged how acceptable the sentences sounded on a 7-point scale (1= “totally natural”; 7=“totally unnatural”).

Lastly, the participants completed two surveys about their attitudes regarding different English dialects in general. In the first survey, the participants answered questions about their attitudes towards their own way of speaking and whether they had an accent. Participants answered questions about traveling to a different dialectal area, and if they adapted to their new linguistic environment by changing their accent or dialect. The survey also asked if others would notice the participant’s own accent or dialect, and whether anyone ever made explicit comments and judgements about their speech. Next, participants answered questions about how difficult it is to understand other dialects, or if they think certain dialects sound more appealing than others. Finally, the participants judged the grammatical acceptability, and indicated how often they hear or use sentences like *The car needs washed* and other unrelated dialectal constructions (e.g., *The grocery store only sells organic produce anymore*). In the second debriefing survey, the participants answered questions about the difficulty level of the tasks, and whether they had any difficulties with the tasks overall. Next, the participants answered questions about the first task, the self-paced reading task. Participants answered questions about what sentences sounded unusual or unexpected, and whether they had any difficulties understanding some of the sentences. The survey also asked participants to judge whether the sentences in the self-paced reading task became more complex or easy as the task moved forward.

Data and Analysis

Participant inclusion and exclusion

Half of the participants completed the study with the “needs” condition while the other half of the participants completed the study with the standard condition. Based on the answers participants provided on the surveys at the end of each task about their familiarity with the “needs” construction, participants were split into four groups based on their previous language experience (significant prior experience with the “needs” construction vs. limited prior experience with the “needs” construction) and the training condition that they received (“needs” condition vs. standard condition). This resulted in 19 participants in “needs” condition with prior experience, 21 participants in “needs” condition without prior experience, 15 participants in standard condition with prior experience, and 21 participants in standard condition without prior experience.

Acceptability Task

Although participants completed the self-paced reading task first, here we report the acceptability results to address the first research question concerning the grammatical acceptability of the “needs” construction among participants, who have prior experience with the “needs” construction. The training condition (“needs” condition vs. standard condition) is not the focus in the data because there was no interaction between what training condition the participants received and the prior experience they had with the “needs” construction.

Table 1. Mean Ratings of “Needs” and Standard Sentences for acceptability task (standard deviations in parentheses)

Dialect	Need Rating	Standard Rating
Exp. (N = 34)	2.46 (1.59)	2.09 (1.43)
No exp. (N = 39)	4.88 (1.43)	2.03 (1.30)
Total (N = 73)	3.75 (1.93)	2.06 (1.35)

A repeated-measures ANOVA showed that there was a main effect of sentence type ($F(1,71) = 62.31, p < .001$, partial $\eta^2 = .467$) because the “needs” sentences were rated less grammatically acceptable than the standard sentences overall. There was a main effect of experience ($F(1,71) = 19.58, p < .001$, partial $\eta^2 = .216$) because participants without prior experience with the “needs” construction rated sentences less grammatical overall. There was significant interaction between sentence type and experience ($F(1,71) = 37.13, p < .001$, partial $\eta^2 = 0.343$) because participants with experience with the “needs” construction rated the “needs” sentences differently than the participants without prior experience with the “needs” construction, while both participants with and without experience with the “needs” construction rated the standard sentences about the same.

Self-Paced Reading Task

Reading times were recorded for each word in the sentence. Reading times for all five main regions of interest were analyzed, including the word prior to *needs* (e.g., *oranges*), *needs*, the past participle (e.g., *peeled*), and the two words after the participle (e.g., *before*; *they*). Reading times less than 150 milliseconds and greater than 1500 milliseconds were excluded from the analysis. Reading times were analyzed using repeated measure ANOVAs with time (phase 1 vs. phase 2) as a within-subject variable and task condition (“needs” condition vs. standard condition) and experience with the “needs” construction (experience vs. no experience) as between-subjects variables. The descriptive results are presented in Table 2.

Table 2. Mean reading times (*ms*) for self-paced reading task (standard deviations in parentheses)

Condition; Experience	<i>oranges</i>	<i>need</i>	<i>peeled</i>	<i>before</i>	<i>they</i>
Ph. 1 Needs; Exp. (N = 19)	407 (104)	411 (101)	429 (98)	438 (120)	389 (86)
Needs; No exp.(N = 21)	361 (118)	361 (92)	390 (158)	499 (161)	398 (135)
Standard; Exp. (N = 15)	402 (153)	388 (110)	399 (190)	381 (107)	362 (101)
Standard: No exp.(N = 21)	388 (105)	386 (84)	370 (83)	371 (65)	364 (63)
Ph. 2 Needs; Exp. (N = 19)	390 (94)	373 (79)	379 (87)	406 (86)	343 (54)
Needs; No exp.(N = 21)	340 (111)	341 (105)	350 (104)	373 (116)	349 (90)
Standard; Exp. (N = 15)	342 (109)	372 (120)	330 (128)	367 (134)	311 (72)
Standard; No exp.(N = 21)	359 (125)	347 (82)	338 (104)	323 (76)	316 (68)

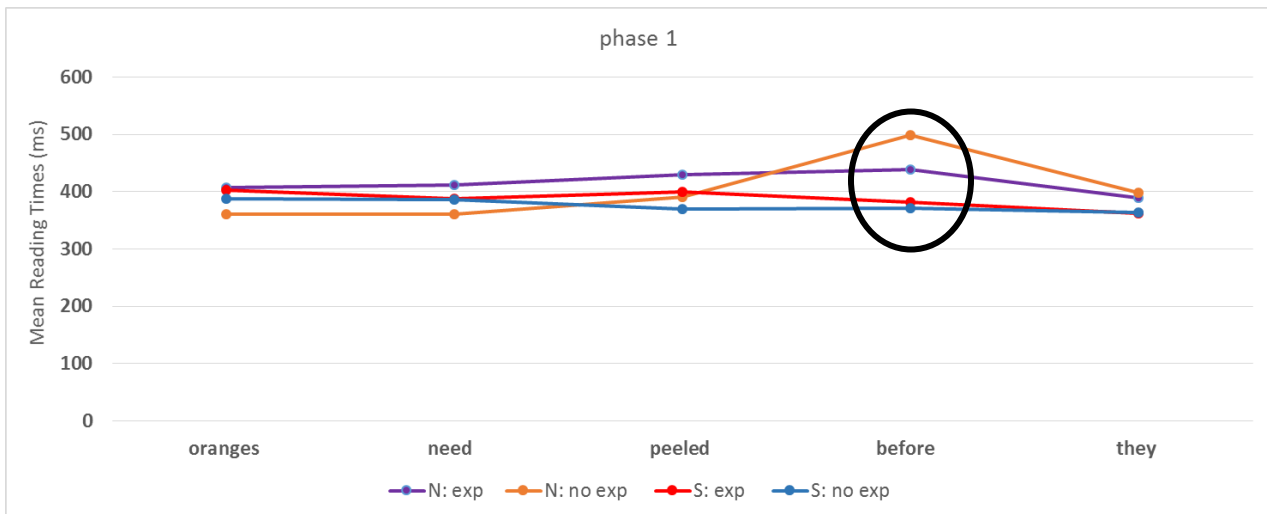
Note: *N*=number of participants; Needs, needs condition; Standard, standard condition; exp. experience with needs construction; no exp. no experience with needs construction.

The results of the ANOVA on the word prior to *needs* (e.g., *oranges*) showed that there was a main effect of time ($F(1, 72) = 9.18, p = .003, \text{partial } \eta^2 = .113$) because in phase 1, reading times were faster than the reading times in phase 2. There were no other significant effects or interactions (task condition: $F(1, 72) = 0.01, p = .928, \text{partial } \eta^2 = .000$; experience: $F(1, 72) = 0.91, p = .343, \text{partial } \eta^2 = .013$; time x task condition: $F(1, 72) = 1.51, p = .221, \text{partial } \eta^2 = .021$; all other interactions $F < 1$).

The results of the ANOVA on the word *need* showed that there was a main effect of time ($F(1,72) = 11.53, p = .001, \text{partial } \eta^2 = .138$) because reading times in phase 2 were faster than the reading times in phase 1. There were no other significant effects or interactions (task condition: ($F(1,72) = .01, p = .926, \text{partial } \eta^2 = .000$); experience: ($F(1,72) = 1.71, p = .196, \text{partial } \eta^2 = .023$); time x task condition x experience: ($F(1,72) = 1.43, p = .236, \text{partial } \eta^2 = .019$); all other interactions $F < 1$).

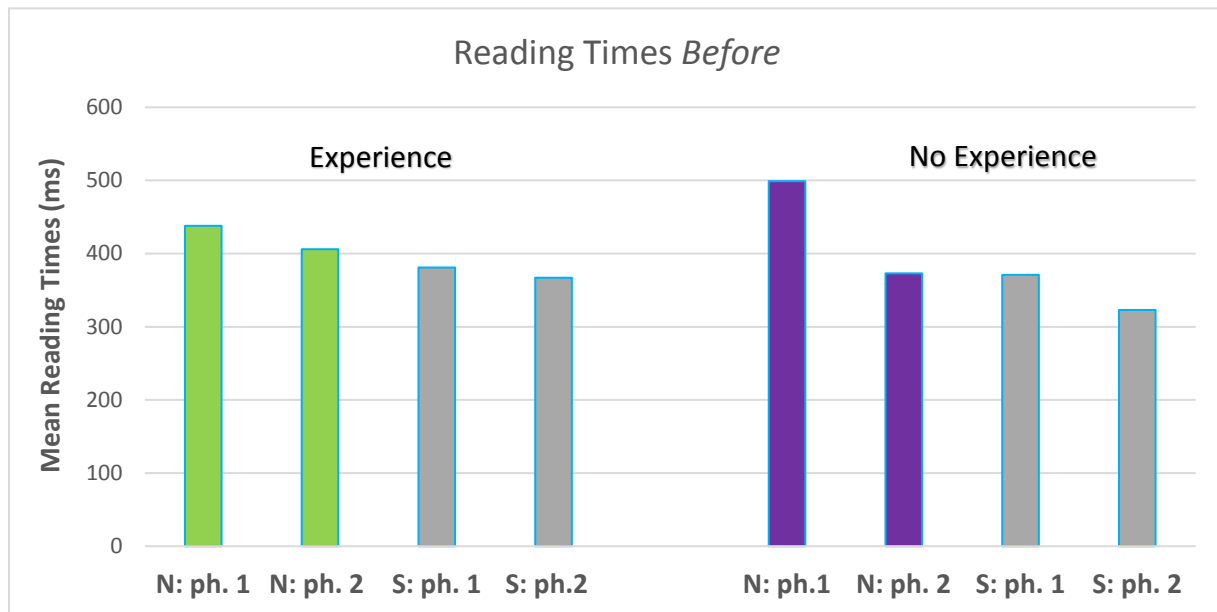
The results of the ANOVA on the past participle (e.g., *peeled*) showed there was a main effect of time ($F(1,72) = 21.21, p = <.001, \text{partial } \eta^2 = .228$) because reading times were faster in phase 2 than the reading times in phase 1. There were no other significant effects or interactions (task condition: ($F(1,72) = 1.17, p = .284, \text{partial } \eta^2 = .016$); time x experience:($F(1,72) = 1.26, p = .266, \text{partial } \eta^2 = .017$); all other interactions $F < 1$).

Figure 1. Mean Reading Times on Phase 1 for each word in the sentence.



Note: N:exp, “Needs” Condition/Experience; N:no exp, “Needs” Condition/No Experience; S:exp, Standard Condition/Experience; S:no exp, Standard Condition/No Experience.

Figure 2. Reading Times from Phase 1 to Phase 2 on the Word after the Past Participle (e.g. *before*)



Note: N: ph.1, “Needs” Condition/Phase 1; N: ph.2, “Needs” Condition/ Phase 2; S: ph.1, Standard Condition/Phase 1; S: ph.2, Standard Condition/Phase 2.

The results of the ANOVA on the word first after the participle, (e.g., *before*) showed that there was a main effect of time ($F(1,72) = 17.73, p < .001$, partial $\eta^2 = .198$) because reading times were faster in phase 2 than the reading times in phase 1. There was a significant effect on task condition ($F(1,72) = 5.61, p = .021$, partial $\eta^2 = .072$) because participants with “needs” condition exhibited longer reading times than participants in the standard condition (see Figure 1). There was a marginally significant time x experience interaction ($F(1,72) = 3.58, p = .062$, partial $\eta^2 = .047$) because participants with prior experience with the “needs” construction exhibited similar reading times in phase 1 ($M = 438$ ms) and phase 2 ($M = 406$ ms), while participants with no prior experience exhibited faster reading times in phase 2 ($M = 373$ ms) than in phase 1 ($M = 499$ ms) (see Figure 2). There were no other significant effects or interactions (time x task condition: ($F(1,72) = 1.33, p = .253$, partial $\eta^2 = .018$; all other interactions $F < 1$).

The results of the ANOVA on the second word after the participle, (e.g., *they*) showed that there was a main effect of time ($F(1,72) = 31.37, p < .001$, partial $\eta^2 = .303$) because reading times were faster in phase 2 than the reading times in phase 1. There were no other significant effects or interactions (task condition: ($F(1,72) = 2.87, p = .094$, partial $\eta^2 = .001$; all other interactions $F < 1$).

General Discussion

The present study investigated whether people familiar with the “needs” construction viewed the “needs” construction as grammatically correct and whether dialect experience

influences an individual's expectations during real-time language comprehension. The following is a summary of the major results of the acceptability task, the self-paced reading task, and the debriefing survey:

- When rating “needs” sentences and standard sentences, participants, who had experience with the “needs” construction, rated the “needs” construction as more grammatically acceptable than the participants, who did not have experience with the “needs” construction. The participants rated standard sentences as grammatically acceptable, regardless of whether they had prior experience with the “needs” construction or not.
- Reading times on all words, from Phase 1 of the self-paced reading task to Phase 2 of the self-paced reading task, decreased overall for all participants.
- There were no differences in reading times for the word prior to *need* (e.g. *oranges*), the word *need*, and the past participle (e.g., *peeled*) as a function of training condition or experience.
- At the word immediately after the past participle (e.g. *before*), there was a significant effect on task condition because participants with “needs” training condition exhibited longer reading times than participants in the standard training condition. The results of the study revealed marginally significant interaction on time and experience because the participants with experience with the needs construction and received the needs condition have similar mean reading times from Phase 1 to Phase 2, while participants without experience with the needs construction and received needs condition have faster mean reading times from Phase 1 to Phase 2.

When looking at the results of the study, the acceptability task results revealed that standard sentences, which are more common in American English, were rated as more grammatically acceptable than the “needs” sentences, which are less common in American English overall. People with prior experience with the “needs” construction rated the “needs” construction as more grammatically acceptable while people without prior experience with the “needs” construction rated the “needs” construction as less grammatically acceptable. These findings do not parallel the previous findings of how increased exposure to an unfamiliar syntactic construction leads to increase grammatical acceptability of that unfamiliar syntactic construction (Luka & Barsalou, 2005) because participants, who were unfamiliar with the “needs” construction, even when exposed to the construction, did not rate the “needs” construction with increased grammatical acceptability over time when exposed to the construction.

The self-paced reading task revealed no reading time differences prior to the disambiguating region of the sentence. Prior to encountering the novel portion of the sentence, there were no differences between the groups of participants. Therefore, participants across the four groups of the study did not vary greatly in reading times or reading speed more generally, prior to encountering the disambiguating region of the sentence.

For the past participle (e.g. *peeled*) and the word after the past participle (e.g. *before*), it was predicted that participants with experience with the “needs” construction would be faster at reading these words than participants without experience with the “needs” construction. It was

also predicted that participants with the “needs” training condition would take longer to read “needs” sentences than participants, who read standard sentences. The present study revealed that the predictions were accurate pertaining to the “needs” or standard condition: Participants, who had the “needs” training condition, had slower reading times for the word after the past participle (e.g. *before*) than participants in the standard training condition. These findings are similar to previous studies, which have shown that syntactic constructions that are less common in a language, such as the “needs” construction, are more difficult to comprehend than syntactic constructions that are more common in a language (e.g., Wells et al., 2009). The results of the self-paced reading task, even though not significant, revealed that participants, who did not have experience with the “needs” construction and received the “needs” training condition, had faster reading times, from phase 1 to phase 2 of the experiment. These findings confirm previous studies’ findings of rapid adaptation to novel or less-frequent syntactic constructions over time (Fine et al., 2013; Fraundorf & Jaeger, 2016 Kaschak & Glenberg, 2004; Wells et al., 2009).

The present study does not support the predictions about participants with prior experience with the “needs” construction having faster reading times because the results showed that participants, in the “needs” training condition, exhibited longer reading times on the word after the participle (e.g. *before*) than participants, who had the standard training condition, regardless of whether they had prior experience with the “needs” construction or not. This suggests that prior experience with a certain syntactic construction does not always lead to greater facilitation when processing that construction during language comprehension (cf. Kaschak & Glenberg, 2004).

The present study revealed a marginal interaction between experience and time at the word after the past participle (e.g., *before*). Participants who had prior experience with the “needs” construction, especially those in the “needs” training condition, did not exhibit faster reading times from phase 1 to phase 2 on the word after the past participle (e.g. *before*), while participants who did not have experience with the “needs” construction had faster reading times on this word in phase 2 as compared to phase 1. The participants with prior experience with the “needs” construction do not adapt as well to the “needs” construction when reading these sentences in real-time. We hypothesize that participants, who have prior experience with the “needs” construction, know that the construction is non-standard, so they have a harder time reading sentences containing this construction, hence the slower reading times on the word after the past participle (e.g. *before*). This is explained because they use this construction only in oral speech and do not encounter it in writing. Therefore, reading the “needs” construction on the computer is novel for participants with experience with the “needs” construction. The survey results show that thirteen participants, who had experience with the “needs” construction, rated the “needs” construction as non-standard and only acceptable to use in informal contexts. Reading is a more formal way of communication than oral speech. Over time, participants, who had prior experience with the “needs” construction, did not read the sentences faster because they knew it was not an appropriate context for this construction. Therefore, the participants with prior experience with the “needs” construction did not adapt as well as the participants without prior experience with the “needs” construction.

Limitations and Future Directions

Even though the results from the present study parallel many of the findings from previous research, there were still limitations and future directions that need to be addressed. The present study had fewer participants than other previous studies. In the future, additional data should be collected in order to have greater statistical power to detect what are often subtle differences in reading times, to more accurately capture how language experience and dialect use can impact real-time reading comprehension. Another factor to expand on is other non-standard or dialectal constructions. Would the results reported here be similar for other syntactic constructions said in the same regions of Central/Western Pennsylvania and Ohio? Will a main effect on dialect and real-time reading comprehension occur if there is more time to experiment with the participants? Furthermore, would foreign language experience affect real-time language comprehension on American English? Finding concrete answers to these questions would provide further insight into language experience and its effect on reading comprehension.

Conclusion

The present study investigated the links between language experience with the “needs” construction and grammatical acceptability and how dialect experience influences an individual’s expectations during real-time language comprehension. Results of the present study showed that experience with the “needs” construction led to greater grammatical acceptability of the “needs” construction. The results of the present study also revealed that dialect had less influence on language comprehension, as measured by reading times in the self-paced reading task. We can have difficulty with reading a syntactic construction that we have prior experience with. With these results, we gain additional knowledge about the comprehension of novel or less frequent constructions and adaptation of constructions due to experience with language (Fine et al., 2013; Fraundorf & Jaeger, 2016; Kaschak & Glenberg, 2004; Wells et al., 2009). Most individuals have their own dialect and idiolect that is unique to them. Communication is an important aspect of every individual’s life, and learning about how different dialects affect how we comprehend language and speak to one another is paramount for understanding conversation and communication more generally.

Appendix A

For each “needs” sentence below (1), a standard sentence and comprehension question will follow. For filler sentences (2) and modifier sentences (3), a comprehension question will follow.

“Needs” and Standard Sentences

- (1) a. The back window needs cleaned before our parents get here.
The back window needs to be cleaned before our parents get here.
Is the back window dirty?
- b. The white fence needs painted to keep the tenants happy.
The white fence needs to be painted to keep the tenants happy.
Are the walls white?
- c. The old chair needs fixed so the guests can sit on it.
The old chair needs to be fixed so the guests can sit on it.
Is the chair old?
- d. The computer program needs debugged before I hand it in.
The computer program needs to be debugged before I hand it in.
Is the computer program broken?
- e. Florida oranges need peeled before they can be eaten.
Florida oranges need to be peeled before they can be eaten.
Are the oranges from Florida?
- f. The large pumpkin needs carved before it can be put on display.
The large pumpkin needs to be carved before it can be put on display.
Is the pumpkin small?
- g. Small potatoes need boiled before they can be used in the soup.
Small potatoes need to be boiled before they can be used in the soup.
Are the potatoes for the salad?
- h. The term paper needs revised before tomorrow morning.
The term paper needs to be revised before tomorrow morning.
Is the paper already finished?
- i. The cotton pants need ironed before you wear them.
The cotton pants need to be ironed before you wear them.
Are the pants made of wool?
- j. The light bulb needs changed since it just burned out.
The light bulb needs to be changed since it just burned out.
Is the light bulb still working?

Filler Sentences

- (2) a. The man must charge his iPad first before he can play the game.
Is the iPad currently charged?
- b. The kids wanted to stay up late to watch the horror movie.
Were the kids already asleep?
- c. The athlete must run ten miles in order to finish the race.
Is the race five miles long?
- d. The little baby must stand up first before she can learn to walk.
Can the baby already walk?
- e. The obese woman may have to exercise more in order to lose weight.
Is the woman overweight?
- f. The student has to do his homework so that he does not fail the course.
Is the homework required?
- g. The teachers should go to all of the meetings in order to get all of the information.
Is information presented at the meetings?
- h. We might have to stay in today due to the flood warning.
Is there a flood warning?
- i. The girl drinks juice whenever she gets thirsty.
Does the girl drink water?
- j. The teacher buys more colored pencils because the old ones were broken.
Are the new colored pencils broken?
- k. The pupil erases the board because the teacher asked him to.
Does the teacher erase the board?
- l. Sally goes to the movies with her brother while the friends all go to the park.
Do the friends go to the movies?
- m. The water went down the drain because the plug was pulled out.
Did the water go down the drain?
- n. The man jumped on the trampoline while the woman waited her turn.
Did the man take his turn first?
- o. The girl played with the doll while her brother played with the truck.
Was the girl playing with a doll?
- p. The janitor grabbed a mop because he spilled water in the basement.
Did the janitor spill water?
- q. The boy is doing math homework while his sister glances at the newspaper.
Is the boy looking at the newspaper?

- r. The children are playing on the playground behind the school.
Are the children in front of the school?
- s. The girls are selling cookies at a booth right next to the supermarket.
Are the girls selling candy?
- t. The sisters are brushing their teeth because it is almost time for bed.
Is it almost time for bed?
- u. Mary was flying her kite in the park when she heard thunder and ran inside.
Was there thunder?
- v. The boy is eating supper with his family in front of the television.
Is the boy eating with his family?
- w. The new clothes were bought by my mother.
Did the daughter buy the clothes?
- x. The glass cup was blown over by the wind during a storm.
Was the cup made of plastic?
- y. The test was graded by the teaching assistant because the instructor was sick.
Was the teaching assistant sick?
- z. The children were picked up by their neighbor because their father was still at work.
Was the neighbor still at work?
- aa. The letter was composed by Natalie during her time away from home.
Did Natalie spend time away from home?
- bb. This medicine is recommended by the doctor to cure many illnesses.
Did the doctor make a recommendation?
- cc. The truck was damaged by a deer that accidentally ran onto the highway.
Did the deer damage the truck?
- dd. The apartment lease was signed by the student before he moved in.
Did the student sign a lease?
- ee. The race car driver should not drive on the back roads because he might get lost.
Would the driver get lost on the main roads?
- ff. It may be faster to travel by airplane to London.
Is it fastest to travel by boat?
- gg. Fred might go to the concert so that he can have fun.
Is Fred considering going to a concert?
- hh. The couple wanted to dance at their wedding for the entire night.
Did the couple want to dance?
- ii. The girl picks up all of her toys because her mother told her to.
Did the father tell the girl to do something?

jj. The teacher has some free time now since her meeting was canceled.

Does the teacher have a meeting now?

kk. The struggling author scribbles down all of his ideas in his journal every day.

Does the author have a journal?

ll. The young boy feeds his cat every morning before school.

Does the boy have a cat?

mm. The kittens are playing with the ball of yarn in the corner by the sofa.

Are the kittens in the middle of the room?

nn. The man is working on his newest novel while sitting at a café.

Is the man working at home?

oo. The horses are galloping along the grass to the barn.

Are the horses heading towards the barn?

pp. The package was delivered by the mailman last Monday afternoon.

Did the package arrive on Tuesday?

qq. The delicious brunch on Sunday was made by my grandmother.

Was the brunch on Saturday?

rr. The broken laptop screen was replaced by the technician with an advanced degree.

Was the laptop broken?

ss. The clown was hit by a cake during the circus performance.

Was the clown in the circus performance?

Modifier Sentences

(3) a. The antique car needs washed hubcaps so that it will be in top condition for the parade.

Will the antique car be in a parade?

b. The patio needs covered tables in case it rains.

Is there a chance it will rain?

c. The legal file needs completed documents before it can be closed.

Can the case be closed before the documents are complete?

d. The tuxedo jackets need folded handkerchiefs in the front pocket so that they look more formal.

Should the handkerchiefs go in the front pockets?

e. The apple pie needs baked walnuts to be placed on its crust.

Is the pie made out of apples?

f. The chicken needs roasted garlic so that it is spicy enough.

Is the chicken already spicy?

g. The new screws need tightened bolts to keep them in place.

Are the screws old?

- h. The meal needs cooked vegetables to make it more balanced.
Are the vegetables part of the meal?
- i. The white wine needs refrigerated grapes to complement it.
Is the wine red?
- j. The auto workers need paid vacation to be included in their next contract.
Are the workers demanding pain vacation?
- k. The beautiful picture needs trimmed edges to hold it in the frame.
Does the picture belong in a frame?
- l. The pork chops need glazed pineapples according to the recipe.
Does the recipe call for apples?
- m. The bottle needs recycled content in order to be labelled as environmentally friendly.
Are bottles without recycled content environmentally friendly?
- n. The kitchen needs scrubbed floors in order to pass the health inspection.
Is the kitchen already clean?
- o. The lawyer's brief needs written statements so that it sounds more official.
Will the brief sound official without written statements?
- p. The air conditioner needs rebuilt gears to be installed.
Should rebuilt gears be installed in the air conditioner?
- q. The restaurant needs lighted candles to improve the romantic ambience.
Is there already sufficient ambience in the restaurant?
- r. The living room needs decorated walls so that it does not appear old and shabby.
Is the living room old and shabby?
- s. The gigantic telescope needs repaired lenses in order to function properly.
Is the telescope currently functioning properly?
- t. The literary magazine needs edited poems before it can be printed.
Has the literary magazine already been printed?

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Effects of Molecular Orientation on Surface-Enhanced Vibrational Spectroscopies

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ABSTRACT

Both surface-enhanced Raman spectroscopy (SERS) and surface-enhanced hyper-Raman spectroscopy (SEHRS) allow for an increased spectral signal from molecules oriented on or near the surface of a metal nanoparticle. It is important to understand how the orientation of a molecule affects its enhanced spectra. In this work, electronic structure simulations were combined with the dressed-tensor formalism to simulate SERS and SEHRS spectra of a water molecule and a benzene molecule on the surface of or in the vicinity of an Ag nanoparticle. Through the simulations, it is found that the distance between the water molecule and the nanoparticle, whether ω was on resonance, and the inclusion or exclusion of field gradient effects impact the enhancement of the SERS and SEHRS spectra. It is also shown that rotational motions of a water molecule or a benzene molecule near a nanoparticle's surface influence the SERS and SEHRS spectrum observed as well.

INTRODUCTION

Raman is a vibrational spectroscopy that can be used to get information about the structure of molecules and how they behave in their environment under certain conditions.^{1,2} The observation of a molecule through these spectroscopies is dependent on the detection of frequencies that correspond to a molecule's normal modes. A normal mode is the synchronous motion of atoms or groups of atoms in a molecule that are excited without also causing the excitation of any other normal modes and the translation or rotation of the molecule. In order for a normal mode of a molecule to be observed in Raman spectroscopies, it must be Raman active, which requires a vibrational motion to occur with a change in polarizability.²

If a molecule's modes are Raman active, then a spectrum can be observed. In the two photon process of Raman spectroscopy, the incident photon can either scatter at a frequency or wavelength equal to (Rayleigh), less than (Stokes), or more than (anti-Stokes) its original frequency upon collision with a molecule. Stokes and anti-Stokes are the two types of Raman scattering that can be observed in Raman spectra.² Hyper-Raman spectroscopy is the nonlinear

version of Raman. Hyper-Raman spectroscopy can give complementary information to Raman, but instead of a two photon process, hyper-Raman utilizes three photons, such that there are two photons with the wavelength ω causing excitation, and then a single photon is scattered with a wavelength of $2\omega'$. The corresponding hyper-Raman line can be observed at the wavelength equal to the difference between the sum of the two incident photon energies and that of the single scattered photon.³

Unlike normal Raman and hyper-Raman spectroscopies, SERS and SEHRS require the use of metal nanostructures. Metal nanoparticles are used to enhance the signal because Raman and hyper-Raman are weak processes. Both the interactions between light and molecules and those between light and metal nanostructures must be considered in order to understand SERS and SEHRS. The light-metal interactions involved with these metal nanostructures can be explained through the concept of surface plasmon resonance (SPR).⁴

SPR is a coherent oscillation of the surface conduction electrons excited by EM radiation. Materials with a negative real and small positive imaginary dielectric constant are capable of supporting a SPR. Plasmonics involves the study of the SPR light-matter interactions, and surface-enhanced spectroscopies are among the array of its applications.⁵ Plasmonic metal nanostructures allow for the enhancement of the spectroscopies of molecules that are in contact with their surfaces.⁶ Thus, with the incorporation of a plasmonic nanoparticle (NP), enhanced Raman or hyper-Raman spectra of molecules oriented on or near the surface of such a NP is possible through SERS and SEHRS.⁷

The NP's strong local electric field allows for the possibility of single-molecule vibrational spectroscopy, and the spectral enhancement of the linear Raman and the nonlinear hyper-Raman vibrational spectroscopies is orders of magnitude greater than if they were not surface-enhanced by the use of metal nanostructures. These spectroscopic enhancements provide intensified signals and thus aid in the interpretation of a molecule's vibrational spectra. It is understood that the enhancement of the vibrational signal comes from a combination the electromagnetic (EM) mechanism and the chemical mechanism (CM). The EM mechanism occurs because of the strong local electric field at the NP surface caused by plasmon resonance, and the CM involves all of the other surface-molecule interactions.⁶

The majority of the enhancement is through the EM mechanism contribution, which is thought to enhance the signals by $|E^{loc}|^4$ for SERS, where E^{loc} is the local electric field the molecule experiences.⁸ The CM, however, does not contribute much to the total spectral enhancement. For SEHRS, the EM mechanism contribution to the enhancement coefficient is roughly scaled to $|E^{loc}|^6$. With the use of the dressed-tensor formalism, the EM mechanism of SERS and SEHRS can be understood and the incorporation of molecular orientation and field gradient (FG) effects in the simulated spectra is possible as well. When FG effects are included in calculation, then the molecule experiences an inhomogeneous local electric field, whereas if FG effects are not included, then the local electric field is homogeneous.⁶

It is important to understand how both field gradient effects and the orientation of a molecule affect its enhanced spectra. In this paper, a combination of electronic structure simulations and

the dressed-tensor formalism was used to simulate the SERS and SEHRS spectra of a water molecule and a benzene molecule on the surface of or in the vicinity of a silver NP. Through the simulations, it is found that whether the incident wavelength was on resonance, the inclusion or exclusion of field gradient effects, and the distance between a molecule and the nanoparticle impact the enhancement of the spectra. It is also shown that the orientation of the molecule near a nanoparticle's surface influences the enhancement observed as well.

THEORY

The SERS intensity for any active normal mode can be written as $I^{SERS} \propto \left| \frac{\partial \alpha}{\partial Q} \right|^2 \times |E^{loc}|^4$,

where α is the dipole-dipole polarizability, Q is the normal mode coordinates for a particular vibration, and E^{loc} is the strong local electric field from the excited nanoparticle that the molecule experiences. Likewise, the SEHRS intensity can be written as $I^{SEHRS} \propto \left| \frac{\partial \beta}{\partial Q} \right|^2 \times |E^{loc}|^6$, where β is the hyperpolarizability. It can be said that for a small spherical metal nanoparticle, $E^{loc} \sim \frac{A}{d^3}$, where A is some constant and d is the distance between the center of mass of the nanoparticle to that of the molecule of interest. If this approximation for E^{loc} were to be inserted into the I^{SERS} and I^{SEHRS} equations previously discussed, it would be expected that the enhancement factors would scale to approximately the 12th power for SERS and the 18th power for SEHRS when investigating the distance dependence for water and the silver nanoparticle. This expectation is based upon no FG effects taken into account in the calculations. However, the inclusion of FG effects introduces other EM mechanisms, which change the predicted values of the enhancement factors. Evidence of this will be presented in this work.⁶

COMPUTATIONAL DETAILS

The Dressed-Tensors Formalism. The dressed-polarizability formalism was used for all SERS and SEHRS simulations of water and benzene. In this formalism, the molecular transition polarizabilities were dressed using electric dipole–dipole (α), dipole–quadrupole (A), and quadrupole–quadrupole (C) transition polarizabilities for water's three normal modes and benzene's thirty. The polarizabilities for these two molecules were rotated to match their corresponding orientation in the silver nanoparticle reference frame. The local field enhancement matrices, which involve the incident field direction and the resulting field (or gradient) directions, were assumed to be identical at both the incident and scattered frequencies. The electric field and field gradient for the nanoparticle were calculated based upon an isotropic sphere, using the experimental dielectric functions of silver with incident light wavelengths of 343 nm for water and for benzene in Raman and at both 343 nm and 686 nm for water and at 686 nm for benzene in hyper-Raman.⁹

Quantum Mechanical Calculations. A local version of the Amsterdam Density Functional (ADF) program package was used for all quantum mechanical calculations involved in this work. For the geometry optimization and normal mode calculations, the local-density approximation (LDA) exchange correlation (XC)-potential and the triple zeta with one polarization function

(TZP) Slater type basis set was used, and the 1s core was kept frozen for oxygen for water and the 1s core was also kept frozen for carbon for benzene. The harmonic approximation was used to analytically calculate the vibrational frequencies and normal modes for the molecules of interest.

The polarizabilities and other properties needed for the normal and dressed-tensor Raman and hyper-Raman frequency independent simulations were calculated using the similar basis set previously described for geometry optimization and normal mode calculations with the 1s core kept frozen for oxygen for water, and the 1s core kept frozen for carbon in benzene. Frequency independent α , A , and C tensors were calculated using the AOResponse module implemented in ADF. Numerical three-point differentiation with respect to the Cartesian normal mode vibrational displacements was used to calculate the tensor derivatives. No symmetry was included in these calculations.⁹

RESULTS AND DISCUSSION

Distance Effects on Spectral Enhancement Factors. The spectral enhancement factors were roughly estimated based upon the best fit line generated for the normalized scatter plot of the recorded intensities of each of water's three vibrational modes 1556 cm^{-1} , 3690 cm^{-1} , and 3794 cm^{-1} over each translation distance in Bohr. The relation used to generate these best fit lines was $I \propto \frac{A}{d^{-x}}$ where I is the intensity of an observed spectral normal mode, A is a constant, and d^{-x} is the distance between the center of mass of the nanoparticle to that of the water molecule raised to some enhancement factor x . Figure 1 is an example of a such a plot for one of the SERS cases, and the data for all generated plots is located in Table 1. From the collected data, it is clear that as the NP was translated farther away from the molecule, the intensities of the spectra decreased. This is likely due to the decrease in local field strength the molecule felt as it became more separated from the NP's surface. How rapid the intensity drop-off was as the molecule was moved from the surface of the NP outward determined the x value. The inclusion of FG effects increased the value of x in all SERS and SEHRS spectra. In most instances, the incident wavelength (ω) used in SEHRS calculations impacted the enhancement factor as well.

Table 1: The collected distance dependence data for all generated normalized scatter plots in SERS and SEHRS.

Vibrational Spectroscopy	SERS	SERS	SEHRS	SEHRS	SEHRS	SEHRS
Field Gradient Effect	No	Yes	No	No	Yes	Yes
Incident Wavelength	343 nm	343 nm	343 nm	686 nm	343 nm	686 nm
Enhancement Factor	$x = 12$	$x = 14$	$x = 16$	$x = 14$	$x = 22$	$x = 22$

For SERS without FG effects at ω on resonance at 343 nm, the enhancement factor x was equal to 12. With FG effects, this factor increased by two orders of magnitude, such that 14 was the enhancement factor. When SEHRS was analyzed at the same ω with FG effects, $x = 22$ whereas without FG effects, the enhancement factor was four orders of magnitude less at $x = 16$. For SEHRS with FG effects at an incident ω off resonance at 686 nm, $x = 22$ whereas without FG effects $x = 14$ which is eight orders of magnitude less.

Clearly, the increase in the magnitude of the enhancement factors in all SERS and SEHRS spectra indicates that the spectral intensities for the normal modes decreased at a faster drop-off rate with FG effects compared to without. It can be seen that for the hyper-Raman plots at both 343 nm and 686 nm incident light frequencies with FG effects, the enhancement factor was $x = 22$. Whether or not the incident wavelength was on resonance had no perceivable effect on enhancement between these two particular spectra. However, for the hyper-Raman plots at both $\omega = 343$ nm and 686 nm without FG effects, the enhancement factor was two orders of magnitude smaller for the off resonance incident wavelength 686 nm.

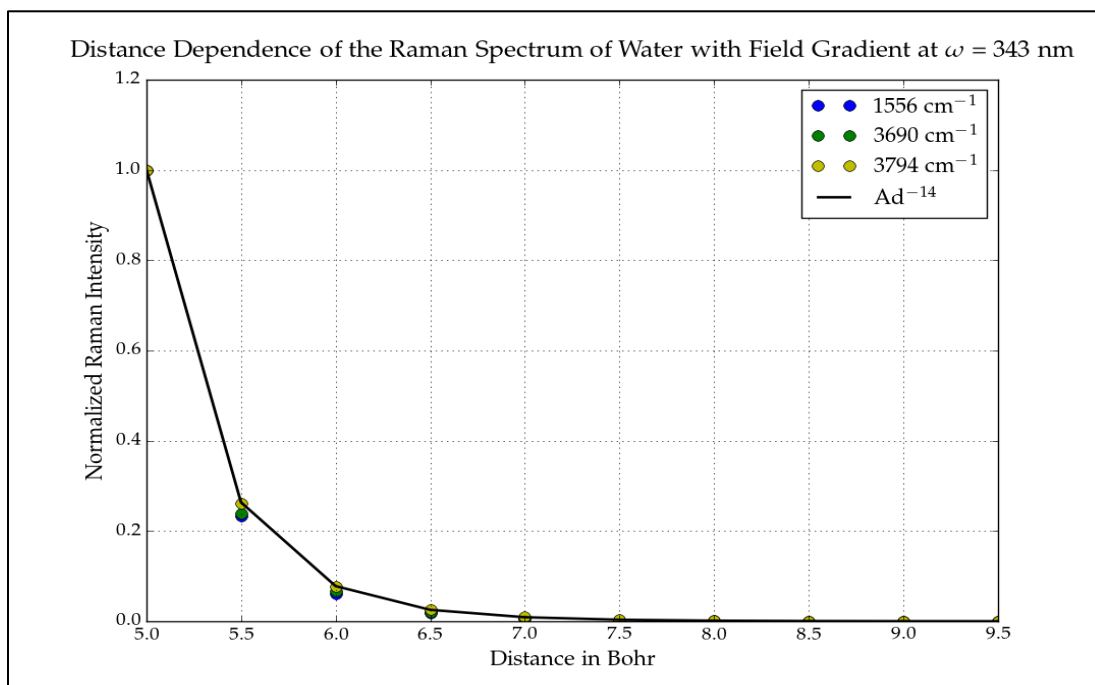


Figure 1: The normalized scatter plot of the SERS intensities of water observed as the molecule was translated farther from the nanoparticle. At distance 5.0 Bohr, the water molecule is at the surface of the silver NP of radius 5.0 Bohr. The enhancement factor here was 14.

Orientation Effects on the Enhancement of Spectra. The orientation effects were observed through the simulated normal and enhanced Raman and hyper-Raman spectra of both water and benzene by changing the orientation of the silver NP of radius 10 Bohr to be on either side of the molecule on the x, y, and z axes of the 3D Cartesian coordinate system. The water molecule's

coordinates lied in a y-z plane where the oxygen atom lied along the negative y-axis and one hydrogen atom was located in quadrant III and the other in IV. Benzene's coordinates were in a x-y plane where the origin was the center of the molecule. Field gradient effects were also included and excluded for the spectra generation.

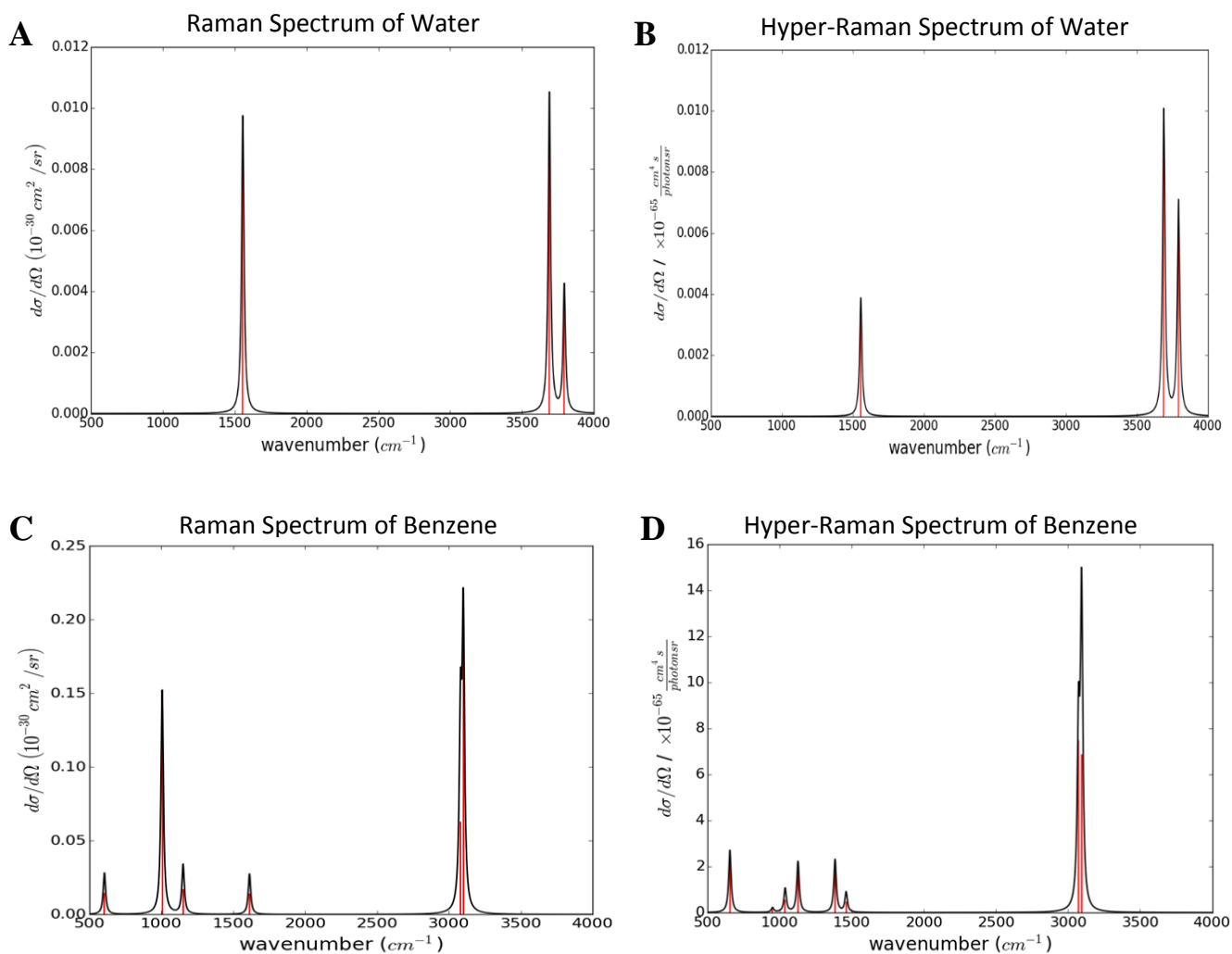


Figure 2: **A**, **B**, **C**, and **D** are the simulated normal Raman and hyper-Raman spectra of water and benzene. The scaled intensity for water's Raman and hyper-Raman's observed normal modes was $1.2 \times 10^{-32} \frac{cm^2}{sr}$ and $1.2 \times 10^{-67} \frac{cm^4s}{photon sr}$ respectively. For benzene, the scaled intensity for Raman was $2.5 \times 10^{-31} \frac{cm^2}{sr}$ and for hyper-Raman it was $1.6 \times 10^{-64} \frac{cm^4s}{photon sr}$.

It can be seen from **A** and **B** that water's three normal modes are present for both the normal Raman and hyper-Raman spectra, while **C** and **D** show that for benzene, there are normal modes observed in hyper-Raman that are not seen in Raman. The magnitude of the enhancements for all of the SERS and SEHRS spectra from Tables 2, 3, 4, and 5 were obtained from the comparison of the normal spectra's scaled intensities mentioned in the description of Figure 2 to that of the

surface-enhanced spectra. For water, all of the simulated SERS and SEHRS spectra had the same normal modes present as the normal spectra and only the intensities of these modes changed.

Table 2: The SERS enhancement data based upon the orientation of the NP to the water molecule and its normal Raman spectrum's intensity.

Axis of Rotation	X		Y		Z	
Field Gradient Effect	No	Yes	No	Yes	No	Yes
Enhancement	250	500	667	1.5×10^3	583	8 1.3×10^4

Table 3: The SEHRS enhancement data based upon the orientation of the NP to the water molecule and its normal hyper-Raman spectrum's intensity.

Axis of Rotation	X		Y		Z	
Field Gradient Effect	No	Yes	No	Yes	No	Yes
Enhancement	42	208	1.2×10^3	1.2×10^4	1.7×10^3	10 1.7×10^5

It can be clearly seen from Tables 2 and 3 that for both SERS and SEHRS, the orientation of the NP relative to the water molecule did not change the enhancement of the resulting spectra for the x and y axes. Whether the FG effects were included or not did change the enhancement observed, however. It can be said that the axis of rotation makes a difference for enhancement as well. The y-axis orientations had higher enhancements than the x-axis orientations. For the z-axis, there was a large difference in the enhancement for one orientation compared to the other for the SERS and SEHRS cases, including FG effects, and these values are emphasized in boxes in the tables.

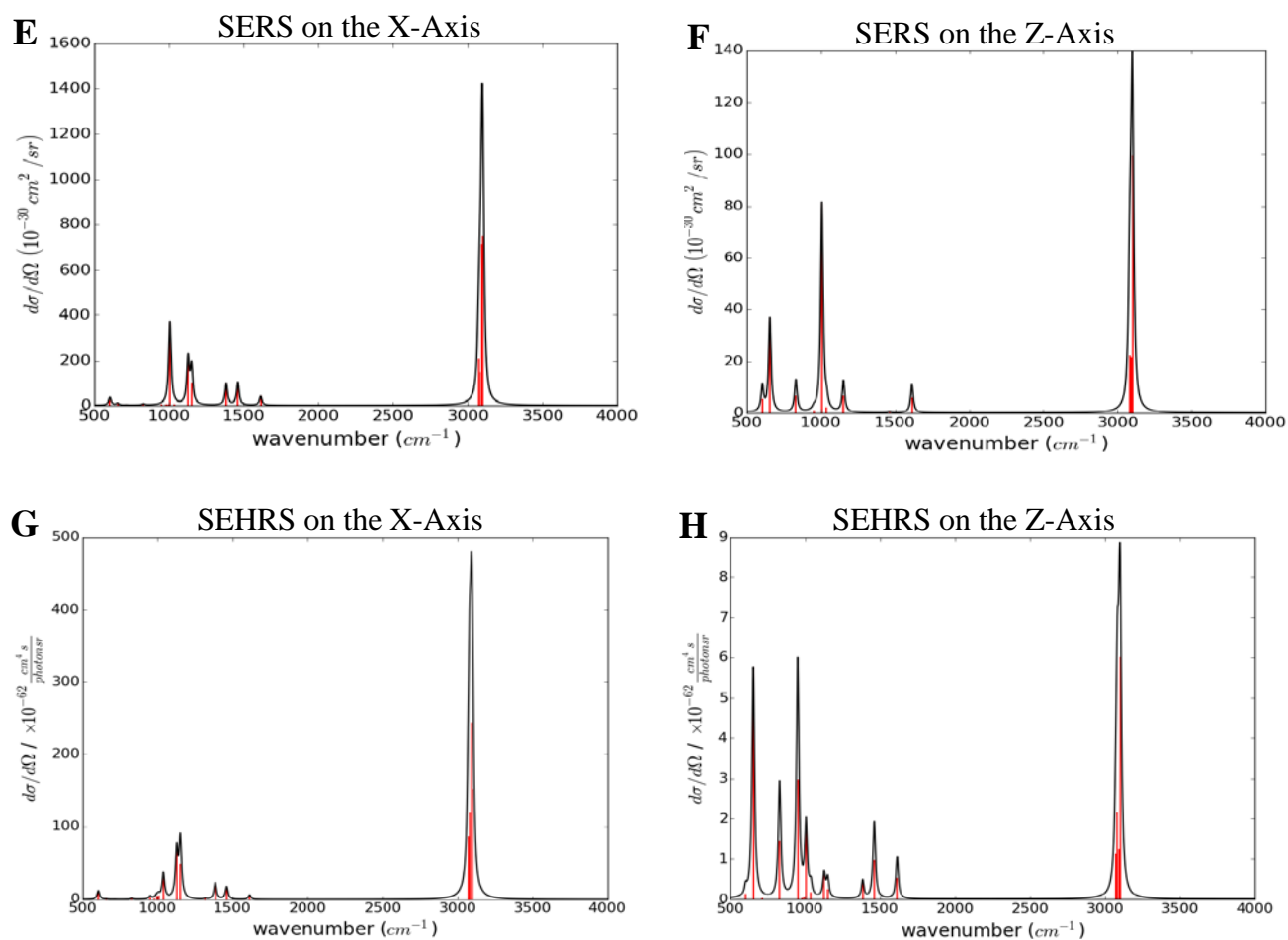


Figure 3: **E**, **F**, **G**, and **H** are the simulated SERS and SEHRS spectra of benzene for the x and z axes of rotation.

For benzene, the x and y-axis orientation spectra had the same observable modes and only the intensities of the peaks changed. However, it can be noted from Figure 3 that new modes were observed when comparing the x-axis spectra **E** and **G** to the z-axis spectra **F** and **H** for SERS and SEHRS as well as when comparing only **F** and **H**. This indicates that the orientation of the molecule as well as the method of spectroscopy can affect the normal modes that are able to be observed in spectra. Tables 3 and 4 provide the SERS and SEHRS enhancement data for benzene when compared to the normal spectrum's scaled intensities from **C** and **D** in Figure 2.

Table 4: The SEHRS enhancement data based upon the orientation of the NP to the benzene molecule and its normal Raman spectrum's intensity.

Axis of Rotation	X		Y		Z	
Field Gradient Effect	No	Yes	No	Yes	No	Yes
Enhancement	1,000	6.4×10^3	1,000	6.4×10^3	80	320
	480	4.0×10^3	480	4.8×10^3	320	560

Table 5: The SEHRS enhancement data based upon the orientation of the NP to the benzene molecule and its normal hyper-Raman spectrum's intensity.

Axis of Rotation	X		Y		Z	
Field Gradient Effect	No	Yes	No	Yes	No	Yes
Enhancement	156	1.6×10^4	188	1.9×10^4	125	562
	1.3×10^3	3.1×10^4	1.3×10^3	7.5×10^4	156	500

From Tables 4 and 5, it can be seen that for benzene the orientation does change the enhancement for all of the axes, not just for the z-axis with FG effects included like water. When the data from Tables 2, 3, 4 and 5 are considered, it is clear that for both water and benzene, the inclusion of FG effects leads to a larger spectral enhancement.

CONCLUSIONS

There are a few conclusions that can be made from all of the data and spectra presented in this work. From the distance dependence data, it is clear that the molecule of interest must be at the surface of the NP for the best enhancement to occur. As the molecule is translated farther from the surface of the NP, the strong local electric field becomes less of an influence on the molecule, and thus the enhancement of the spectra decreases. Distance dependence data from Table 1 supports the conclusion that including FG effects leads to a faster intensity drop off for observed spectra, which leads to an increase in enhancement. Also, Table 1 shows that the predicted values of the enhancement factors of 12 for SERS and 18 for SEHRS discussed in the **THEORY** section were not in agreement with the factors found through simulation. This

indicates that the inclusion of FG effects introduces other EM mechanisms, which can change these values. It is also seen from Table 1 that the incident wavelength exciting the molecule can affect the enhancement factor of SEHRS spectra. An ω on resonance with the excitation wavelength of the plasmonic NP had a larger enhancement factor and thus a larger spectral enhancement than an incident wavelength that was off resonance.

From the orientation data in Tables 2, 3, 4, and 5, it is clear that certain orientations provide larger enhancements. Thus orientation is an important factor to consider when attempting to detect molecules of interest. It can also be seen from **A**, **B**, **C**, and **D** from Figure 2 and **E**, **F**, **G**, and **H** from Figure 3 that there are normal modes observed in SEHRS spectra that are not seen in SERS spectra. Figure 3 also shows that orientation can have an influence on what normal modes are observed as well.

A final conclusion to be made is that molecules can be identified by their unique Raman spectrum. This can be said because for water, there were three distinct normal modes that were consistent in appearance through all spectra, thus water could be easily identified using a reference spectrum. Also, for benzene, the normal modes that consistently appear in the fingerprint region of 500-2,000 cm^{-1} could be used for identification.

Future work will include the simulation of the spectra of larger molecules using similar methodology that was used for water and benzene. Molecules such as naphthalene and anthracene would logically be the next two molecules of interest as they build off of benzene. Also, it would be interesting to use metal nanoparticles of different geometries other than just the small spherical model. The investigation of the spectral enhancements that arise from these other geometries and how they compare to previously collected data from the spherical model is certainly an interest for future work.

ACKNOWLEDGEMENTS

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Road Friction Estimation from Tire Forces Transferred Through Steering Rod

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Abstract

This research investigates a method of estimating road friction using steering linkage measurements of the dynamic tire aligning moment. The linkage forces act on the steering and suspension geometry of a specially instrumented steer-by-wire test vehicle that has a load cell on the steering arm of each front tire. Changes in forces measured within the geometry of the suspension cause aligning torques on the tire which are nonlinearly related to road friction. Because dynamic vertical tire forces also produce lateral forces on the steering linkage, the estimation of friction effects requires accurate kinematic estimation of the tire loads in order to isolate the tire aligning moment from the total linkage force. Accurate friction detection is the first step in implementing a control system that can detect and minimize the effects of road departure, particularly in low-friction situations.

INTRODUCTION

In the United States of America, the number of fatal vehicle crashes due to unintended roadway departures (URD) is over fifty percent [1]. Due to the frequency with which URD occurs, researchers have sought methods of detecting URD, particularly using vision-based sensors on the vehicle. These vision-based sensors seek to detect the location of the lane markers and thereby help the driver stay on course.

However, lane markers are not always visible or detectable by these sensors. The sensor may fail to recognize lane markers in bad weather conditions, or the sensor will not find markers if the road is unmarked. The limited capability of vision-based sensors presents a problem, as it is necessary to have road departure detection methods that work in all road and weather conditions. This paper investigates the viability of detecting changes in road friction, measurable in vehicle dynamic anomalies, as an alternative means of URD detection.

Much of the prior work done in road friction estimation focuses on situations where the vehicle is traveling on a flat road [2]. This is an assumption that greatly influences the behavior of the vehicle, specifically the loads acting on each individual tire. Situations where weight transfer is important include pitch and roll weight transfers caused by superelevation or severe cornering. The goal of this paper is to show the effects of these weight transfers on normal tire loads, which then affect vehicle dynamics. The first part of the paper covers the method of friction estimation in this work. This is then followed by the calculations to determine accurate tire normal loads due to various vehicle states. Following this is a description of the test vehicle

and experimental tests. The latter portion of the paper compares experimental data with simulation results.

METHODOLOGY

A. Friction Estimation Approach

The approach investigated by this paper to estimate road friction calls upon the measuring of tire forces on a test vehicle’s steering rod. The term “steering rod” is used interchangeably with “tie rod” throughout this paper. The steer-by-wire vehicle used in this study is equipped with force transducers on both the left and right front axle tie rods. The measured force will reflect the tire forces transferred through the suspension. The self-aligning moment and forces transferred due to tire loads sum at the tie rod transducer. By performing a subtraction of normal tire load contributions to the sum of forces on the tire rod, the remaining force is expected to be due to the lateral force producing the self-aligning moment. A relationship between the lateral force, the coefficient of friction and the normal force at tire contact patch can then be determined.

Outlined in this paper are methods for accurately modeling tire loads when considering changes in ride height and weight transfer when a vehicle is cornering or on a super elevated road for example. An accurate estimate of tire loads is necessary for robust implementation of the proposed friction estimation. The following sections show the calculations for normal loads due to static weight, pitch weight transfer, and roll weight transfer.

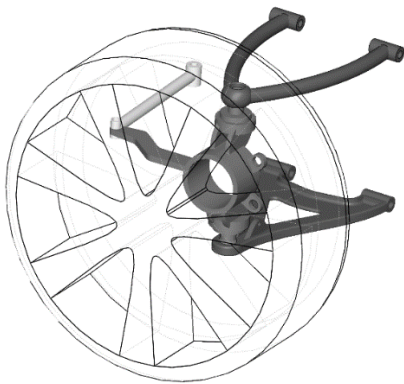


Figure 1: Isometric view of double wishbone

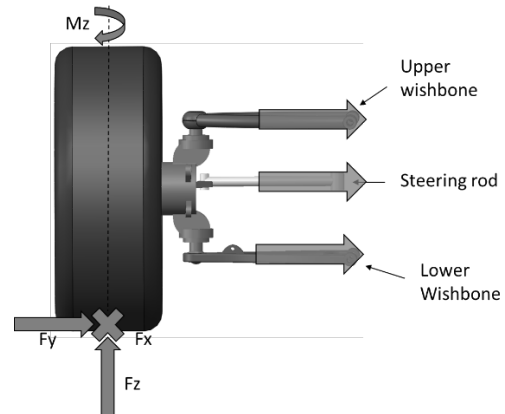


Figure 2: Rearview of tire forces transferring lateral suspension forces into suspension

B. Normal Tire Load Calculations

The normal force at the tire contact patch is derived here for the situation of static equilibrium on a half car model. It is assumed that the left and right sides of the car are identical and symmetrical. Static equilibrium means the sum of forces and torques on the vehicle are equal to zero.

$$\sum M_y = 0 \quad \sum F_z = 0$$

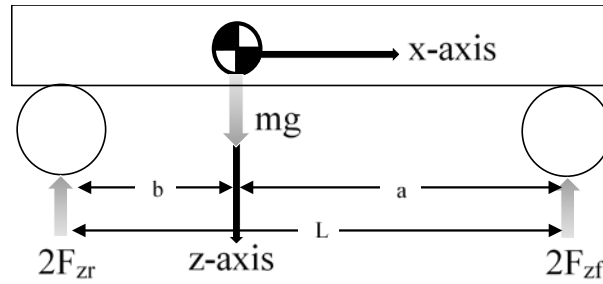


Figure 3: Side view of vehicle model in static equilibrium

The forces acting on the half car model are its weight, located at the center of gravity (CG) location, and the normal force at the front and rear axles. The front axle is a distance “a” from the CG and the rear axle a distance “b” from the CG. The normal forces on the axles depicted below include the normal force for the right and left axles. The distance from the front axle to the rear axle is the wheelbase (L).

The sum of the forces is:

$$2F_{zf} + 2F_{zr} - mg = 0$$

The sum of the moments about the CG is:

$$2F_{zf} a + 2F_{zr} b = 0$$

Solving this system of equations yields the following results for the normal force acting on each of the front axle tires and rear axle tires:

$$F_{zf} = \frac{mg b}{L} \quad F_{zr} = \frac{mg a}{L}$$

C. Front to back weight transfer due to longitudinal acceleration (pitch)

This next case includes a longitudinal acceleration acting on the vehicle center of gravity as follows:

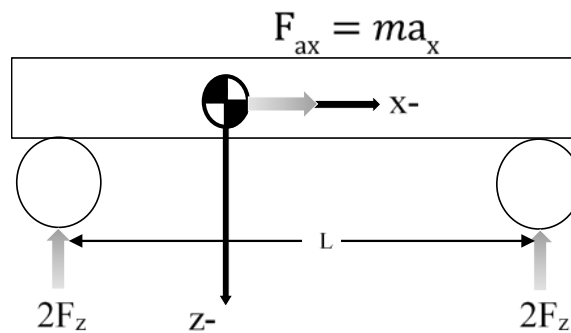


Figure 4: Side view of vehicle model with longitudinal acceleration

The longitudinal force generated at the CG can point to the right or point to the left. This force will produce a moment about the front and rear tire contact points. Ignoring the static weight distribution from the vehicle weight, the sum of the torques can be done about the front contact patch and the rear contact patch to find the extra weight transfer to the rear and front tires respectively.

Summing the moments about the front contact patch results in:

$$\begin{aligned}\Sigma M_{front} &= 0 \\ F_{zf}(extra) &= -ma_x \frac{h}{2 \cdot L} \\ 2 \cdot F_{zr}(extra) \cdot L - ma_x h &= 0\end{aligned}$$

Summing the moments about the rear contact patch results in:

$$\begin{aligned}F_{zr}(extra) &= ma_x \frac{h}{2 \cdot L} \\ 2 \cdot F_{zf}(extra) \cdot L + ma_x h &= 0\end{aligned}$$

This extra normal force at the front and rear tires will be added to the static normal loads calculated earlier. This assumption results in the following equations:

$$\begin{aligned}F_{fl} &= mg \left(\frac{b}{2L} \right) - ma_x \left(\frac{h}{2L} \right) \\ F_{fr} &= mg \left(\frac{b}{2L} \right) - ma_x \left(\frac{h}{2L} \right) \\ F_{rr} &= mg \left(\frac{a}{2L} \right) + ma_x \left(\frac{h}{2L} \right) \\ F_{rl} &= mg \left(\frac{a}{2L} \right) + ma_x \left(\frac{h}{2L} \right)\end{aligned}$$

D. Left to right weight transfer due to lateral acceleration (roll)

Now that longitudinal load transfer has been taken into consideration, the next step is to include lateral acceleration typical of a vehicle going around a curve. At steady state the sum of the torque about either the inside or outer tire should be zero. The extra weight on the outer tire balances out the centrifugal force pulling the car towards the outside of the turn.

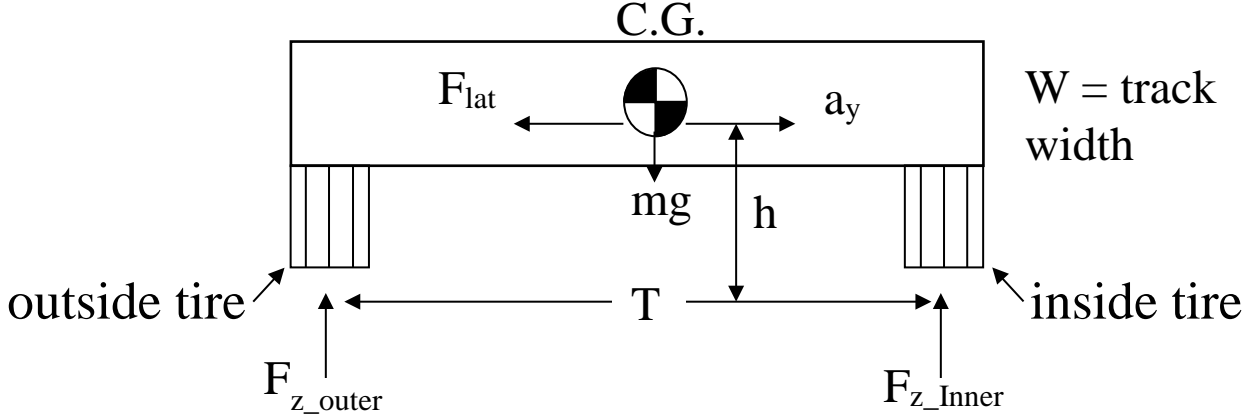


Figure 5: Rear view of vehicle model with lateral acceleration

The sum of the moments about the inside contact point gives:

$$F_{zo}(\text{extra}) \cdot T - F_{lat} \cdot h = 0$$

$$F_{zo}(\text{extra}) = F_{lat} \frac{h}{T}$$

$$F_{lat} = ma_y$$

Similarly, the sum of the moments about the outside contact point:

$$-F_{zl}(\text{extra}) \cdot T - ma_y h = 0$$

$$F_{zl}(\text{extra}) = -ma_y \frac{h}{T}$$

The following equations are the normal forces on each tire with pitch and roll weight transfer terms included. It is assumed here that all tires have no mass:

$$F_{fl} = mg \left(\frac{b}{2L} \right) - ma_x \left(\frac{h}{2L} \right) - ma_y \frac{h}{T} \left(\frac{K_{\phi f}}{K_{\phi f} + K_{\phi r}} \right)$$

$$F_{fr} = mg \left(\frac{b}{2L} \right) - ma_x \left(\frac{h}{2L} \right) + ma_y \frac{h}{T} \left(\frac{K_{\phi f}}{K_{\phi f} + K_{\phi r}} \right)$$

$$F_{rl} = mg \left(\frac{a}{2L} \right) + ma_x \left(\frac{h}{2L} \right) - ma_y \frac{h}{T} \left(\frac{K_{\phi r}}{K_{\phi f} + K_{\phi r}} \right)$$

$$F_{rr} = mg \left(\frac{a}{2L} \right) + ma_x \left(\frac{h}{2L} \right) + ma_y \frac{h}{T} \left(\frac{K_{\phi r}}{K_{\phi f} + K_{\phi r}} \right)$$

THE TEST VEHICLE

The P1 (Fig. 6) was developed by the Dynamics Laboratory and the Product Realization Laboratory at Stanford University. It is a steer-by-wire vehicle which, rather than performing vehicle functions through mechanical linkages, uses instead electro-mechanical systems for steering and throttle inputs (braking inputs are still manual). The P1 vehicle has independent tie motors and independent AC electric drive capability [2]. Onboard P1 there are inertial sensors, steer angle encoders, and a GPS system for obtaining data during test runs.



Figure 6: P1 steer and drive by wire test vehicle

EXPERIMENTAL SETUP

Data collected from P1 during a ramp steer maneuver is used to show the simulation results of accounting for normal tire loads. The experimental run was conducted at The Thomas D. Larson Pennsylvania Transportation Institute's skid pad. The vehicle velocity, tie rod forces, tie angles along other measurements were taken.

Vehicle velocity reached 10 m/s for the initiation of the ramp steer maneuver (Fig. 7). Both simulation runs are not visible in figure 7 because they used the same longitudinal velocity as inputs. A left-hand turn was performed with the steering angle gradually increased until significant oversteer characteristics were observed (Fig. 8 and 9).

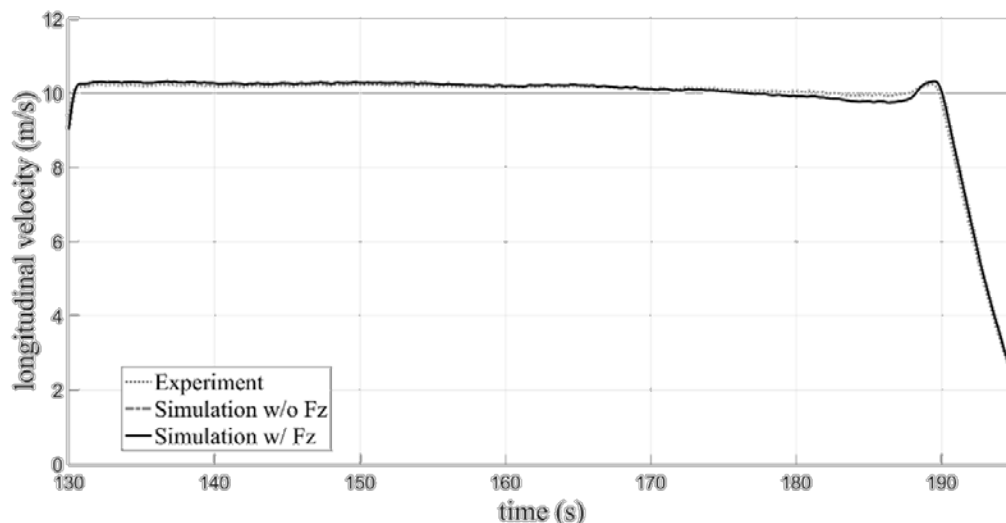


Figure 7: Constant forward velocity during ramp steer test

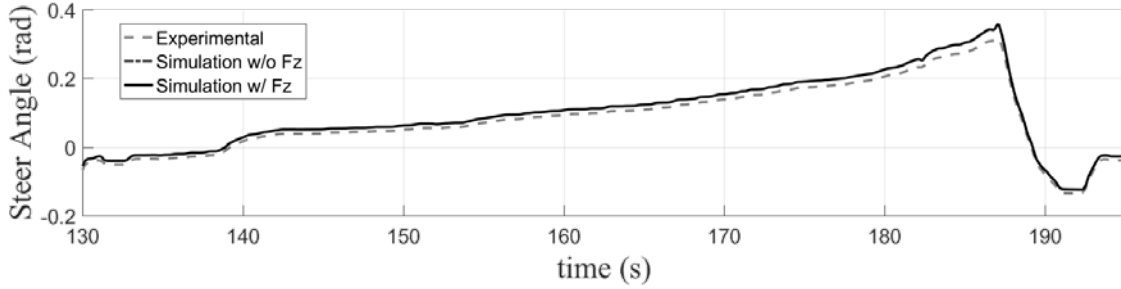


Figure 8: Steering Angle

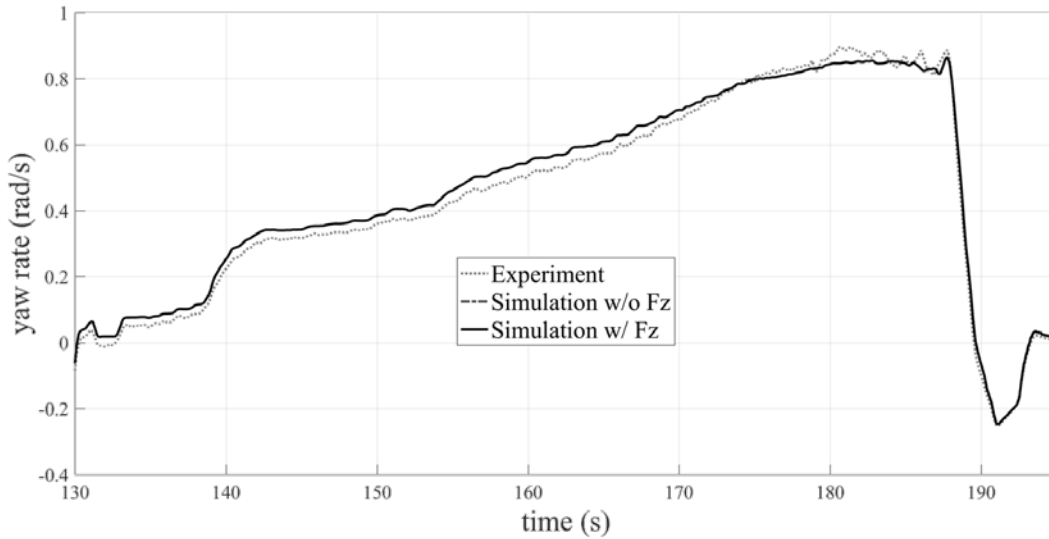


Figure 9: P1 yaw rate during ramp steer maneuver

RESULTS AND CONCLUSIONS

A computer simulation based on blender and MATLAB software uses the inputs of forward velocity and steering angle to produce the plots in figures 10 and 11. The script calculates the force on the steering rod as a result of the forces acting about the tire steering axis. Explaining the plots from top to bottom, this graph shows a much better agreement between simulation and experimental data when we include the normal forces and jacking torques, than if these effects are ignored.

The right steering rod load cell does not show good agreement, which is a result of only slight changes to the outside tire load cell during left-hand cornering. A future research suggestion is to investigate methods for more robust normal load calculations. The next step is isolating the side (lateral) force contribution to the steering rod force by subtracting all other moments producing a force at the steering rod. Finally, a relation can be made between the lateral force and road friction as functions of steering angle.

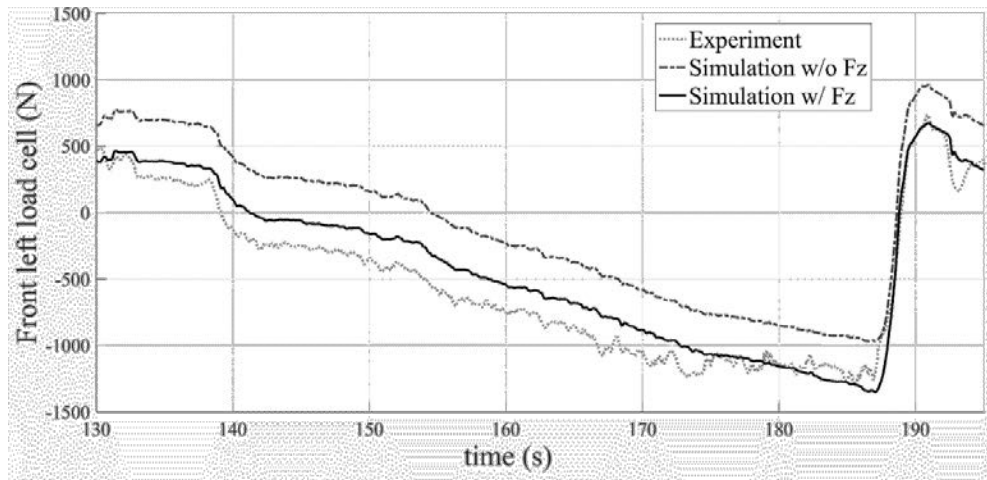


Figure 10: Left Steering rod load cell measurements

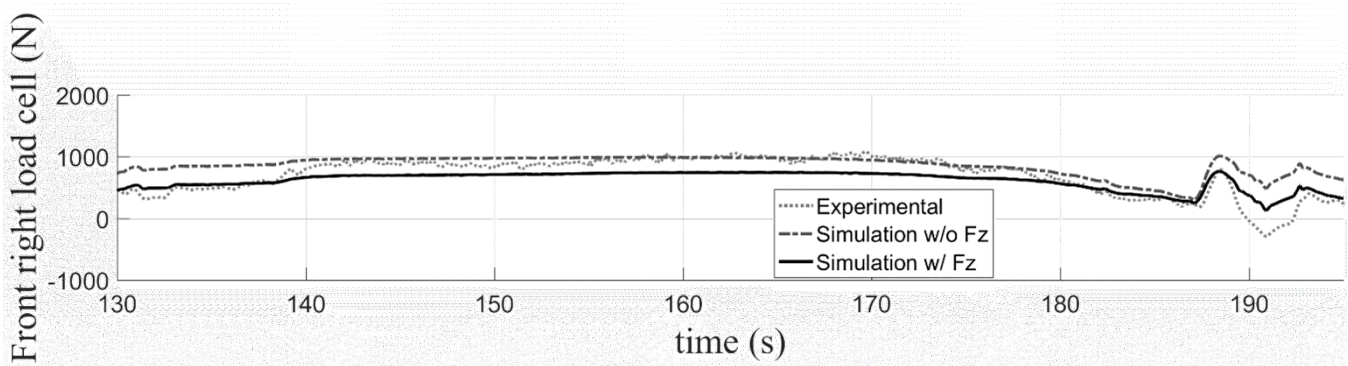


Figure 11: Right steering rod load cell measurements

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