JOURNEY

Letter From The Editors

Dear Reader,
We are excited to present to you the fifth annual volume of JOURney, the University of North Carolina at Chapel Hill's first interdisciplinary Journal of Undergraduate Research!

JOURney started as an idea of founder Gabi Stein to create a journal that would showcase the outstanding, diverse range of student research done by UNC-Chapel Hill undergraduates. With the support of the Office of Undergraduate Research, JOURney became an official publication, allowing students a place to publish SURF projects, partial and full honors theses, and independent research.

This year, JOURney has continued to expand, gaining many successes along the way with the receival of the most-ever number of submissions. With all the excellent work submitted, we are able to exhibit 15 original pieces of work here that explore interesting, topical, and complex areas of research. We congratulate the student authors on all their hard work put into researching and publishing their work!

We are so thankful of everyone who has helped JOURney continue to meet its mission of celebrating and supporting the research conducted early in students' academic careers. We would like to thank the Office for Undergraduate Research, which has provided JOURney unwavering support since its inception. Specifically, we would like to thank Associate Dean and Director Troy Blackburn (Department of Exercise and Sports Science), Associate Director Boots Quimby, and Business Services Coordinator Denise Carter. We would also like to thank our entire editorial board and publicity team, who have spent many dedicated hours into making this edition. As the current Co-Editor-In-Chiefs, we have enjoyed helping JOURney expand as an organization.

We leave you here to explore the work presented in this journal. We hope you will enjoy the knowledge collectively presented to you by the students of UNC-Chapel Hill.

Sincerely,
Mili Dave & Harrison Jacobs
2020-2021 JOURney Co-Editor-in-Chiefs

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Stress as a Risk Factor for Maternal and Infant Mortality Disparities in the United States: *A Comparison of Black and White Women*

by Brianna Halliburton & Jewel Tinsley

In 2018, the national average infant mortality rate for non-Hispanic Black Americans was 10.8 deaths per 1,000 live births, nearly double the U.S. average of 5.7 deaths per 1,000 live births. We hypothesize lifelong maternal stress in Black American women manifests as adverse birth and maternal outcomes. Using data from the 2017-2018 National Health and Nutrition Examination Survey (NHANES), we collected information on biological stress factors and health indicators. We aimed to look at our hypothesized connections between stress indicators and poor maternal and infant outcomes. We expected higher levels of stress indicators in non-Hispanic Black women, therefore supporting a linkage between stress and the observed maternal and infant outcomes. White blood cell (WBC) count and creatinine levels in urine served as biological stress indicators. We cross-examined them with health indicators from surveys, supplying a metric for our sample populations' physical health and access to care. Based on our statistical analysis, access to health insurance and a healthy diet are significantly different between non-Hispanic Black and White women's health which may cause stress. We found significant relationships between elevated levels of biological stress indicators and high blood pressure in non-Hispanic Black women. These results indicate the necessity for medical care to consider sociocultural background and how the manifestation of stress physiologically affects pregnancy outcomes. Although other health indicators may render results unclear, it is evident that Black women and children are dying at much higher rates than White women in the United States, and lifelong stress may be to blame.

Keywords: stress, Black women, maternal mortality, infant mortality

INTRODUCTION

Maternal mortality and infant mortality rates in the United States are at significantly higher levels when compared to other wealthy, industrialized countries (Tikkanen et al., 2020; "International Comparison",2018). The CDC defines maternal mortality or pregnancy-related death as the death of a woman during pregnancy, at delivery, or within one year of the end of the pregnancy, not including accidental or incidental causes of death. The CDC's pregnancy mortality surveillance system reported a national average of 16.7 pregnancy-related deaths per 100,000 live births (Petersen et al., 2019). This ratio is more than double that of other high-income countries like the United Kingdom and Canada, with maternal mortality rates of 6.5 and 8.6 respectively (Tikkanen et al., 2020). In the U.S., there are notable differences in rates across different racial or ethnic groups. The non-Hispanic White pregnancy-related mortality ratio (PRMR) was found to be below the national average at 12.7. In stark contrast, the non-Hispanic Black PRMR was 40.8, more than triple the rate of White mothers. Non-Hispanic American Indian/Alaska Native and Hispanic women had averages of 29.7 and 11.5, respectively (Petersen et al., 2019). These startling figures point to larger disparities and inadequacies of America's health care

system, especially because most maternal deaths are preventable (Tikkanen et al., 2020).

Similarly, infant mortality rates are strikingly high in the United States and differ across racial and ethnic groups. Infant mortality is defined by the CDC as the death of an infant before the age of one. The CDC reports in 2018, the national average was 5.7 deaths per 1,000 live births. The infant mortality rate for non-Hispanic Black Americans almost doubles that rate, at 10.8 deaths per 1000 live births ("Infant Mortality", 2020). Adverse birth outcomes are also disproportionately experienced by Black Americans. Examples of adverse birth outcomes include low birth weight defined as being born at less than 5.5 pounds, or preterm delivery defined as being born at fewer than 37 weeks' gestation. The leading causes of infant deaths were congenital malformations or birth defects (20.9%), short gestation (66%), and low birth weight (17.1%) (Ely and Driscoll, 2020). The increased infant mortality rate in non-Hispanic Black Americans infants is most likely directly correlated to the maternal mortality of non-Hispanic Black Americans, thus explaining why both are significantly higher

than other races of mothers and infants in the United States (MacMurchy, 1925).

After reviewing racial differences in the rates of infant and maternal mortality, the gathered information necessitates further exploration of the causes of such disparities. The overwhelming statistics lead us to ask: "In the United States, why is the infant mortality rate for Black Americans almost two times higher than White Americans and the maternal mortality rate almost four times higher when compared to White Americans?" As we attempted to answer this question, we acknowledged the evident racial disparities in birth and health outcomes and aimed to evaluate the factors that increase these disparities. Taking a sociocultural approach to the biomedical outcomes allowed us to evaluate how Black women's health has been addressed in America and the structural factors that influence mortality rates of infants and mothers. To effectively focus on the physiological and ecological evidence presented in our dataset, we aimed to closely look at the sociocultural context in which the recorded outcomes occurred. This theme is key to our research's understanding of not only lifetime discrimination but also the implications that generational trauma and stress have on the Black women's body over time. We intend to delineate results by examining the dual discrimination that Black women face from both race and gender, which leads to a unique, multifaceted experience with social factors and health trends rooted in structural inequality. We believe these factors are central to understanding and enacting change in the notable disparities between Black and White Americans birth and maternal outcomes.

We hope to gain a better understanding towards the following questions:

1. Why is the maternal mortality rate four times higher for non-Hispanic Black Americans than for non-Hispanic White Americans?
2. What are the factors linking maternal mortality to infant mortality rates in the United States?

BACKGROUND

It is well understood that the health of a mother is causally linked to the health of her child. The health of a pregnant woman does not begin during conception and or end when the woman gives birth, as it lasts throughout the entirety of her reproductive years. Preconception is the term that describes the overall health of non-pregnant women during their reproductive years, and by paying attention to these critical times, maternal and infant mortality can be reduced (Robbins et al., 2018). The reproductive years can be affected by chronic medical conditions, racial disparities, and other behavioral risk factors, such as smoking or alcohol consumption. Each of these risk factors can be associated with maternal and infant mortality and can also lead to preterm birth, low birth weight, and a multitude of birth defects (Behavioral Risk Factor Surveillance System). As noted before, these are the main factors that contribute to infant mortality.

The Behavioral Risk Factor Surveillance System used ten indicators to determine health behaviors and how these may affect maternal and infant health. The indicators were: depression, diabetes, hypertension, current cigarette smoking, normal weight, recommended physical activity, recent unwanted pregnancy, pre-pregnancy multivitamin use, postpartum use of a most or moderately effective contraceptive method, and pre-pregnancy heavy alcohol use. We have modeled our evaluation in an analogous manner, considering similar relevant indicators to determine when and where each health indicator is most present or absent. These indicators can cause adverse outcomes when at unhealthy levels. We wish to examine the prevalence of our indicators in both White women and Black women and evaluate the social and cultural context that may have influenced the onset. Literature suggests (Rosenthal, 2011) that Black women's stress plays a role in the onset of certain risk factors like high blood pressure, which increases the risk of pregnancy complications for mother and child. Relatedly, *intersectionality*, a term coined by Kimberle Crenshaw, describes the multiplicative experience of lifetime discrimination from multiple axes of social stratification. These axes can include race, class and gender. For Black women, there is a unique experience that comes from the lifelong gendered

racism of being both Black and a woman (Crenshaw, 1989). It is this lifetime discrimination that is believed to manifest as stress and have physical implications on the woman's bodily health, and thus the health of her unborn child. A lack of clarity arises in understanding because Black women seem to be thriving in their mental health in the face of intersectional adversity. This is commonly referred to as the Black-White mental health paradox (Keyes, 2009). However, this paradox suggests that the stress may be manifesting in physical outcomes, even if undetected in common biological measures like those reported in NHANES: creatinine and white blood cell count. Relevant literature on Black women's health shows evidence of a higher allostatic load in Black women resulting from repeated or chronic stress exposure (Duru 2012). This heavy allostatic load speeds up her biological clock, which is the physical manifestation of lifelong stress, and is killing Black mothers and children.

We employed a life course perspective to examine childhood development and how it affects health into adulthood. Furthermore, by focusing on cumulative biological stress, we can see how factors associated with stress affect the physiological health of women. With this knowledge, we can differentiate why non-Hispanic Black women in the United States experience such notable disparities when compared to their non-Hispanic White counterparts. Stress is a physiological and psychological experience that results from a disruption to the equilibrium in one's life (Lovallo, 2005). It is a common experience that most people have experienced in some form, and when it is continuous and uncontrolled, it can be dangerous to the body and the health of the individual (Harburg et al., 1973a; Harburg et al., 1973b; Rofé and Goldberg, 1983). These dangerous effects include high blood pressure, kidney damage, and cardiovascular disease (Harburg et al., 1973). Each of these effects can be induced by the overproduction and release of cortisol, the primary hormone brought on by stress (Thau et al, 2020). High blood pressure is an important element to measure in relation to stress because research has shown that stressors trigger the acute stress response, which in turn leads to physiological changes that maintain elevated blood pressure. Therefore, elevated blood pressure could be considered to be indicative of repeated trauma or stress and vice versa. (Larkin, 2005; Jorgensen et al.,1996). Thus, we have chosen to use high blood pressure as one measurement of physiological stress experience. While some cortisol is necessary for living and development, an overregulated exposure to the hormone can have significant effects, such as the ones previously mentioned (Pike, 2005). Cortisol is a steroid hormone which has many functions within the body including stress regulation. When the body experiences internal or external stressors, it stimulates a hormonal response that eventually causes cortisol to be released from the adrenal cortex, allowing the body to remain on high alert (Thau et al., 2021). This is what is often referred to as the Fight-or-Flight response (Lovallo, 2005; Thau et al., 2021). Cortisol has shown to be very sensitive to negative stressors, making it an appropriate variable to measuring stress for the purposes of our study (Lovallo, 2005). Stress can come from work or life experiences such as racial tension or economic disparities (Stress and Your Kidneys, 2020). Furthermore, research has also shown that socioeconomic status, such as the ones previously stated, can influence the life expectancy and quality of life for an individual (Adelman, 2008). Without access to cortisol measurements in the participants within this study, other biological markers were used that are associated with cortisol levels. These markers include white blood cell (WBC) count and creatinine.

WBC count in the body is generally a measure of the body's defense against disease, which is the main job of these inflammatory leukocytes (Carrington College, 2014). Other research has shown that stress increases the WBC count (Cheng, 2014) and thus can be dangerous to health (Carrington College, Cheng, 2014). Increased WBC also releases plaque

buildup in the arteries, also known as atherosclerosis, which is likely why stress is associated with cardiovascular disease and stroke ("Atherosclerosis"; Carrington College, 2014).

Creatinine is a chemical waste molecule generated from muscles metabolism breakdown, which is then filtered through the kidney (Davis, 2021; Creatinine). It is an important indicator of the kidneys health and can be a sign of kidney failure if the levels are too high. Normal levels of creatine in women range from 0.5 to 1.1 milligrams per deciliter (Davis, 2021). There is a significant relationship between an increase in stress or cortisol and an increase in creatinine (Ladesvita et al., 2020). This relationship is evident in physical diseases such as high blood pressure and kidney disease (Ladesvita et al., 2020; Stress and Your Kidneys, 2020)

IMPORTANCE

Understanding health disparities in the United States is particularly important in ensuring care is being provided not just adequately but also curated to the experience of the mother and child. Once disparities like this are acknowledged, research can begin to understand how a mother's health over the course of her lifetime has incredible implications, which differ across racial lines and experiences, on her health as a pregnant woman and on her unborn child. As soon as medical care acknowledges the impact that racial discrimination has on the life trajectory and life outcomes of certain populations, measures can be implemented to address the structural issues that cause population health disparities.

METHODS & SAMPLE

Data Sources

We used the National Health and Nutrition Examination Survey (NHANES) questionnaires and survey data sets from 2017-2018 for our research to get the most accurate information and averages of women inside the United States. The NHANES 2017-2018 questionnaires held relevant information on general health and what we considered to be stress indicators or factors related to stress. We gathered demographic information including age, gender, race, and pregnancy status. Using JMP statistical software, we eliminated those who were outside of the ages of 18-40 years old (the child-bearing age), and only included non-Hispanic White and Black women for further analysis.

Sample Population and Demographic Data

The total survey population included 478 women —205 non-Hispanic Black women and 278 non-Hispanic White women —using data from the 2017-2018 NHANES Survey. The population subsets for the stress indicators, creatinine and white blood cell count, included pregnant women, non-pregnant women, and women who did not report their pregnancy status (listed as N/A). This population was important to focus on because of the documented divide between non-Hispanic White women and non-Hispanic Black women in the United States in terms of health and socioeconomic status (Petersen et al., 2019). We chose not to include women of Hispanic background because we recognized that cultural differences are likely to be present. These cultural differences can lead to different health practices during their reproductive years that would not be in alignment with the goal of our data collection. The same is true for other racial groups in the United States, along with the fact that there is not as significant a difference in the maternal and fetal morbidity and mortality rate between other races as there is between non-Hispanic Black women and non-Hispanic White women. Therefore, with this specific and limited sample population, we can reduce the amount of outside cultural impact unaccounted for as much as possible.

Independent Variables

Another influencer of stress includes culture within the United States and its impact on health and socioeconomics. In order to include these factors efficiently, we combined various available data collections that allowed us to define socioeconomic and health status within study participants. Firstly, these included socioeconomic factors such as family income. By accounting for the annual family income, we can assume individuals of lower income are more likely to have health inflictions than those of a higher income. This assumption can be supported by relating it to the physical and

mental health measurements collected by NHANES through surveys of diagnoses and self-reported measures. These surveys include data pertaining to general health condition, high blood pressure and cholesterol, and diet behavior. Secondly, another measurement of health was based on the amount of personal care that the individual had including the frequency of seeking health care and their insurance status. While these are fundamental for complete personal health maintenance within Western culture, we also recognize that socioeconomic factors may influence our participants' access to these resources.

After acquiring our set demographic, we gathered data on the given population's information to support the previously mentioned independent variables: socioeconomic status (annual income), access to healthcare (health insurance, healthcare place, routine healthcare place), general health, and mental health (depression screen 1 and 2). To gather information for each of the indicators, we used the survey questions and answers from NHANES 2017-2018 from multiple categories. For socioeconomic status, we used family income answers from the Demographic section of the questionnaire (DEMO_J) using the annual family income question (INDFMIN2). To measure healthcare indicators, we looked at the Hospitalization and Access to Care section of the questionnaire (HUQ_J) and looked specifically at the questions pertaining to a routine healthcare place (HUQ030) and type of healthcare place (HUQ0401). Answers to access to health insurance came from the Health Insurance section of the questionnaire (HIQ011). These answers were self-reported and formed our analysis in the Health indicators section.

To measure the mental health status of the participants, we took answers from the DPQ020 and DPQ090, which we refer to as Depression Screen 1 (Over the last 2 weeks, how often have you felt down, depressed, or hopeless?) and Depression Screen 2 (Over the last 2 weeks, how often have you been bothered by the following problems: Thoughts that you would be better off dead or of hurting yourself in some way?). To look at biological health indicators, we used general health conditions, high blood pressure, and a healthy diet. The answers to these questions came from the Current Health Status (HSD010), the Blood Pressure and Cholesterol (BPQ20), and the Diet Behavior and Nutrition (DBQ700) sections of the questionnaire, respectively. These sections were also used to form our analysis of health indicators.

Dependent Variables

We used the variables of white blood cell count and amount of creatinine in urine as a proxy for stress and was collected using the NHANES 2017-2018 laboratory data collection. To gather the creatinine data, we used the Albumin and Creatinine data set (ALB_CR); and once we had our data in JMP, we eliminated the unnecessary measures and used creatinine in urine (mg/dL) (URXUCR). For white blood cell count, we used the Complete Blood Cell Count data set (CBC_J) and extracted the white blood cell count data only (1000 cells/uL) (LBXWBCSI).

In using laboratory data, we can account for the fact that stress is not only psychological but also a physiological occurrence that can have serious effects on the health of an individual. Elevation of WBC count has been shown to correlate with adverse lifestyles, such as an unhealthy diet and an increased risk of coronary heart disease (Nishitani et al., 2014). In general, individuals experiencing high stress are more likely to have increased levels of WBC count, more specifically an increase in leukocytes (Carrington College, 2014). Creatinine is a protein found in the urine that is used to test for kidney health. Elevated levels of creatinine are generally a major sign that a person is experiencing kidney damage. In pregnant women, it is slightly more difficult to be sure what a dangerous amount of creatinine is due to the fact that normal creatinine levels for pregnant women are considered dangerous for nonpregnant individuals (National Kidney Foundation, 2020). Regardless of this, it is still appropriate to use this as a measurement of stress, since all the women in the study are at reproductive age but not all are pregnant. Using these two biological measurements, we

can indicate that stress affects the participants and is a viable reason for their health conditions.

Statistical Analysis
Question 1 (Q1): Why is the maternal mortality rate four times higher for Black Americans than for White Americans?
In order to understand the factors affecting the maternal mortality rate for Black women when compared to White women in the United States, we must look at the influence of both biological and social factors. Table I describes the demographics of the sample population. In order to answer Q1, we ran a linear regression model to determine the correlation between high blood pressure and health insurance with creatinine (See Figures I and II). We also performed a logistic analysis of high blood pressure and health insurance with white blood cell count to further delineate the association between these health factors and the biological health outcome.
Question 2 (Q2): What are the factors linking maternal mortality to infant mortality rates in the United States?
In addition to the statistical analyses for Q1, we used the existing literature and compared it with our descriptive statistics that gave the p value for correlation to answer Q2. We also reviewed the mean values for each independent variable and the overall averages of non-Hispanic White women and non-Hispanic Black women for the dependent variables. Because the health of the mother and child are intrinsically linked, we look to the statistical methods from Q1 in order to gather evidence for infant mortality rate disparities, although we are observing maternal factors.

RESULTS

Socioeconomic Status
Socioeconomic status was found to have significant variation between non-Hispanic Black and non-Hispanic White women. The socioeconomic status of each woman was measured based on family income. Table 1 shows that 34.6% of non-Hispanic Black women compared to 23.8% of non-Hispanic White women were more likely to have a yearly family income of less than $25,000. Furthermore, more non-Hispanic White women have a yearly family income greater than $75,000 with 30.8% of the sample population being included in this subcategory. Far fewer non-Hispanic Black women have a yearly family income within this range with 16.2% of the sample population being included in this subcategory.

Health Indicators
Multiple health indicators were used to indicate the health practices of each woman within these two racial groups. The questions posed for Health Insurance, Healthcare Place, and Routine Health Care serve as metrics for the access to care available to the sample population. The questions posed for Depression Screen 1, Depression Screen 2, Healthy Diet, and General Health Condition supply a metric for the sample population's physical health, shown in Table I and II.

There were multiple significant indicators of health and wellbeing in both populations. Creatinine levels (stress indicator) were found to be statistically significant in non-Hispanic Black women. As reported in Table II, creatinine levels for pregnant Black women had an average of 189.846 Mg/dL, which was higher than the average of 158.167 Mg/dL for non-Hispanic White women. The second stress indicator was white blood cell count, with values seen in Table II. The average white blood cell count was 8.381 cells/μL for White women which was higher than Black women whose average white blood cell count was 7.367 cells/μL. The comparison between non-Hispanic White women and non-Hispanic Black women can also be seen in Figure III, further supporting the claim that non-Hispanic White women have a higher average of white blood cell count. The white blood cell count was highest for non-Hispanic White pregnant women and lowest for non-Hispanic Black non-pregnant women.

Due to there being a marked difference in creatinine levels, we examined the correlation between creatinine and the health indicators that were found to be statistically significant: health insurance and high blood pressure (Figures I and II). The other health indicators also present general information about the survey population. The values related to Figure I and II are being reported

Table I: All Socioeconomic and Health Indicators for Non-Hispanic White and Non-Hispanic Black Women: NHANES 2017-2018

	Race		
	NH White N (%)	**NH Black** N (%)	**All** N (%)
Demographic			
Number of Women	273 (57.11)	205 (42.89)	478 (100.0)
Socioeconomic			
Family Income			
Under $25,000	65 (23.8)	71 (34.6)	136
$25,000 to $55,000	77 (28.2)	64 (31.2)	141
$55,000 to $75,000	40 (14.6)	15 (7.3)	55
$75,000 and Over	84 (30.8)	33 (16.2)	117
N/A	7 (2.6)	22 (10.7)	29
Health Indicators			
Health Insurance: *Do you currently have health insurance?*			
Yes	242 (88.6)	165 (80.5)	407
No	31 (11.4)	40 (19.5)	71
Routine Healthcare: *Is there a place that you usually go when you are sick?*			
Yes	223 (81.7)	162 (79)	385
No place	49 (17.9)	43 (21)	92
More than 1 place	1 (0.4)	0 (0)	1
Healthcare Place: *What kind of place do you go to most often for healthcare?*			
Doctor's Office	165	101	266
Clinic	41	35	76
Emergency room	10	24	34
Outpatient dept	1	1	2
Other	7	1	8
N/A	49	43	92
Depression Screen 1: *Over the last 2 weeks, how often have you felt down, depressed, or hopeless?*			
Not at all	178 (65.2)	138 (67.3)	316
Some days	58 (21.2)	38 (18.5)	96
Most days	16 (5.9)	9 (4.4)	25
Everyday	8 (2.9)	4 (2)	12
N/A missing	13 (4.8)	16 (7.8)	29
Depression Screen 2: *Over the last 2 weeks, how often have you thought that you would be better off dead or of hurting yourself in some way?*			
Not at all	252 (92.3)	187 (91.2)	439
Some days	8 (2.9)	2 (1)	10
N/A	13 (4.8)	16 (7.8)	29
High Blood Pressure: *Have you ever been told by a doctor or other health professional that you had hypertension, also known as high blood pressure?*			
Yes	35 (12.8)	27 (13.1)	62
No	237 (86.8)	178 (86.8)	415
Don't Know	1 (.36)	0	1
Healthy Diet: *In general, how healthy is your overall diet?*			
Excellent	9 (3.3)	10 (15.2)	19
Very good	61 (22.3)	31 (15.1)	92
Good	120 (44)	64 (31.2)	184
Fair	67 (24.5)	79 (38.5)	146
Poor	16 (5.9)	21 (10.2)	37
General Health Condition: *In general, how would you rate your health?*			
Excellent	56 (20.5)	28 (13.7)	84
Good	91 (33.3)	80 (39)	171
Very good	81 (29)	61 (29.8)	142
Fair	39 (14.3)	31 (15.1)	70
Poor	5 (1.8)	5 (2.4)	10
Don't know	1 (0.37)	0 (0)	1

from the data in Table I.
High Blood Pressure
A higher percentage of Black women, at 13.1%, reported being told they had high blood pressure by a doctor or other healthcare professional compared to 12.8% of White women (Table I). The correlation between high blood pressure and creatinine levels in both populations was found to be statistically significant. In Black women, the correlation in Figure I shows that the Black women who reported 'no' to having high blood pressure are less likely to have elevated creatinine levels. In Figure V, we can also see a logistic relationship showing that the number of non-Hispanic Black women who responded 'yes' to having high blood pressure are more likely to have increased white blood cell count.
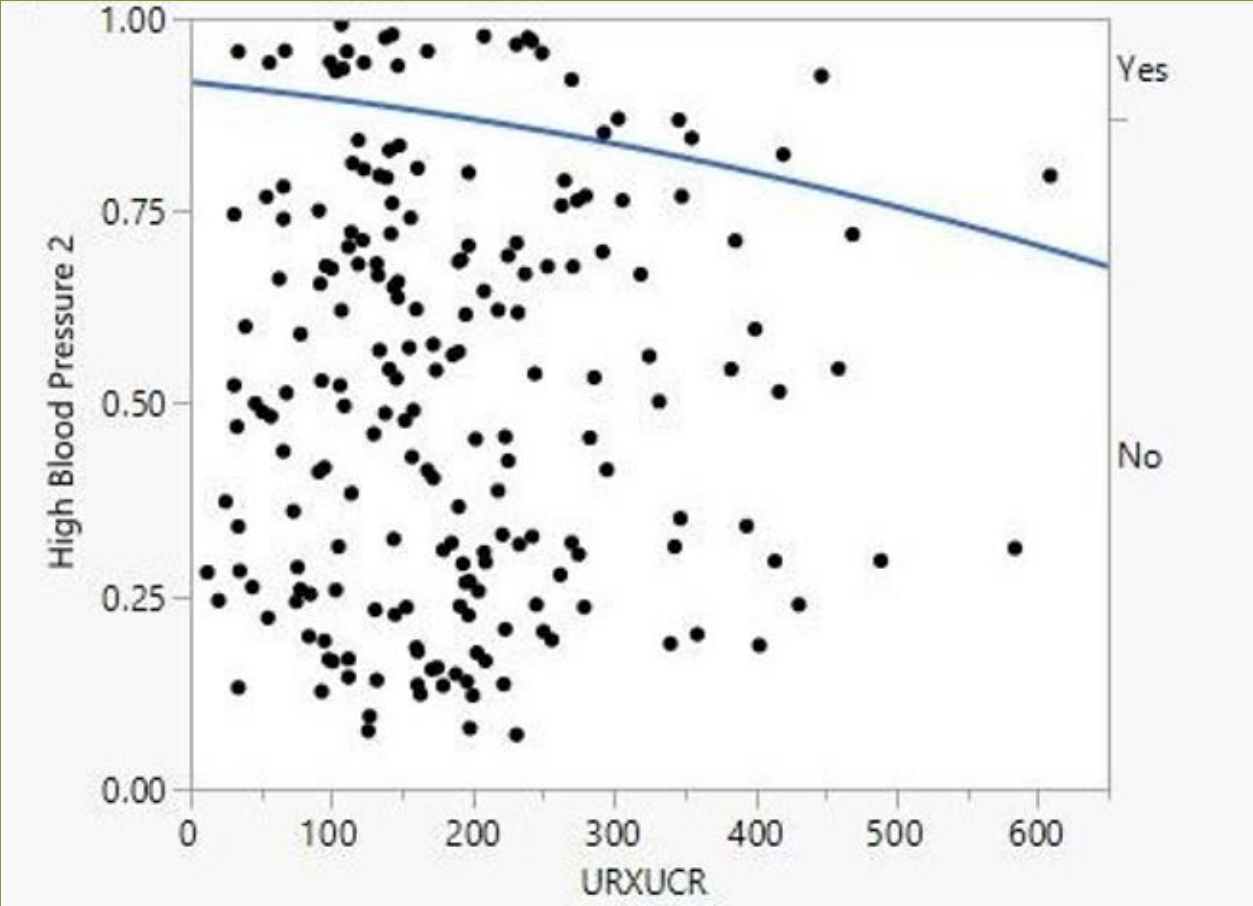

Figure I: Correlation Between High Blood Pressure and Creatinine for NH Black Women
In figure I, we can see the correlation between the diagnoses of high blood pressure and the levels of creatinine found in the urine of non-Hispanic Black women. The study participants who said "no" to being told by a doctor that they had high blood pressure are less likey to hae elevated creatinine levels.

Health Insurance

A higher percentage of non-Hispanic White women reported having health insurance, and a higher percentage of non-Hispanic black women reported not having health insurance. The correlation between health insurance and creatinine levels were found to be statistically significant. The correlation represented in Figure II depicts the findings. There is a limited, slightly positive correlation between health insurance and creatinine. Meaning, that it is more likely that Black women with health insurance had elevated creatinine levels. The logistic analysis in Figure IV shows that when non-Hispanic Black women answered 'no' to having health insurance, they showed an increase in white blood cell count. In Table II, a significant difference was found between the amount of non-Hispanic Black women who self-reported having health insurance versus non-Hispanic White women who reported the same. Only 80.5% of non-Hispanic Black women reported having health insurance compared to 88.6% of non-Hispanic White women.
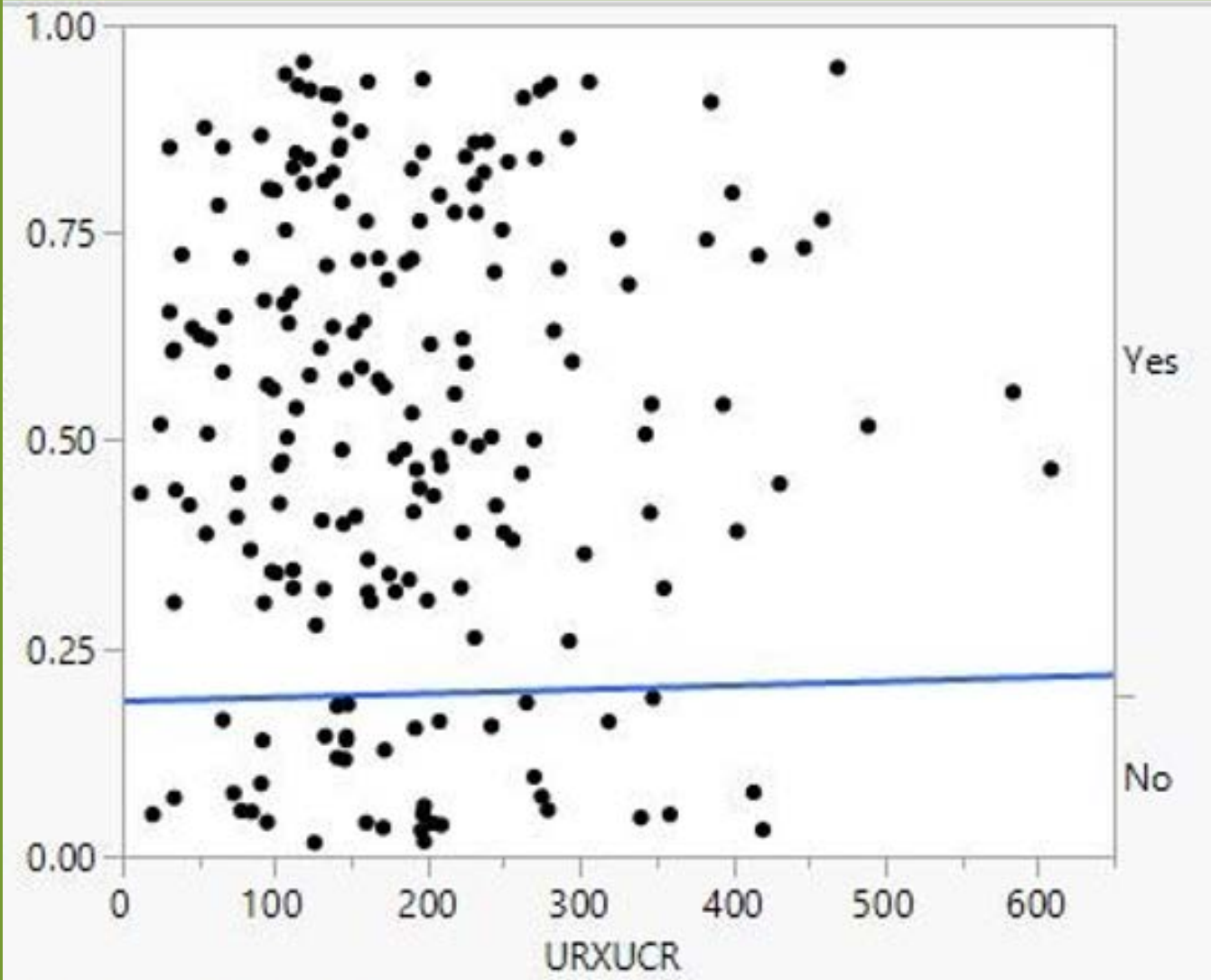

Figure II:Correlation Between Health Insurance and Creatinine for NH Black Women
Figure II: Limited, slightly positive correlation between health insurance and creatinine. Illustrates that it is more likely that those who had health insurance had elevated creatinine levels.

medical attention at an emergency room than non-Hispanic White women.

Routine Health Care

A similar percentage of non-Hispanic White women and non-Hispanic Black women reported having a place where they will usually visit if they are sick. For non-Hispanic Black women, 21% reported not having a routine place to visit when they were sick compared to 17.9% of non-Hispanic White women (Table 1).

Healthy Diet

A higher percentage of non-Hispanic White women reported having a "very good" or "good" diet while a higher percentage of non-Hispanic Black women reported having an excellent diet. In Table II, a significant difference was found between the amount of non-Hispanic Black women who self-reported having a healthy diet versus non-Hispanic White women who answered in the same manner. While 43.9% of non-Hispanic White women reported having a good diet, only 31.2% of non-Hispanic Black women reported having a good diet. However, 38.5% of non-Hispanic Black women reported having a poor diet compared to only 24.5% of non-Hispanic White women.

General Health Conditions

The overall health between non-Hispanic White women and non-Hispanic Black women appeared to be similar except for small variations between the percentage of non-Hispanic Black women (13.7%) and percentage non-Hispanic White women (20.5%) who reported having excellent general health.

Depression Screen 1 and 2

When asked, "Over the last 2 weeks, *how often have you felt down, depressed, or hopeless?*" A higher percentage of non-Hispanic White women on average answered that they have felt down, depressed, or hopeless by responding some days (21.2%), most days (5.9%), or everyday (2.9%). A higher percentage of non-Hispanic Black women, at 67.3%, answered that they have not felt down, depressed, or hopeless at all over the last 2 weeks compared to 65.3% of non-Hispanic White women.

When asked "O*ver the last 2 weeks, how often have you thought that you would be better off dead or of hurting yourself in some way?*" the results were similar: 92.3% of non-Hispanic White women and 91.2% of non-Hispanic Black women answered, "not at all."

Table II: Sample Descriptive Statistics

Variable	NH White		NH Black		NHW vs. NHB % Diff.
Health Indicators					
Independent Factors					
% Health Insurance-Yes	88.6%		80.5%		**
% Routine Healthcare-Yes	81.7%		79.0%		
% Depression 1-not at all	65.2%		67.3%		
% Depression 2-not at all	92.3%		91.2%		
% High Blood Pressure-Yes	13.2%		12.8%		
% Healthy Diet- Good	43.9%		31.2%		**
% General Health Condition- Good	33.3%		39.1%		
	Mean	*SD*	*Mean*	*SD*	
Age (Years)	30.0	5.91	30.4	5.69	-1.33%
WBC	8.01	2.09	6.60	2.22	17.6% ***
Creatine Level	127.4	87.6	186.8	109.5	-46.6% ***

% Diff= Change between NH White women vs NH Black women as baseline

p=* < 0.05, **<0.01, ***<0.001

WBC= White Blood Cell count (1000 cells/uL), Creatinine level= urine measurement (mg/dL)

Healthcare Place

When questioned about where they visit most often for healthcare when sick, both non-Hispanic Black women and non-Hispanic White women reported primarily going to a doctor's office. More non-Hispanic Black women reported that they were most likely to seek
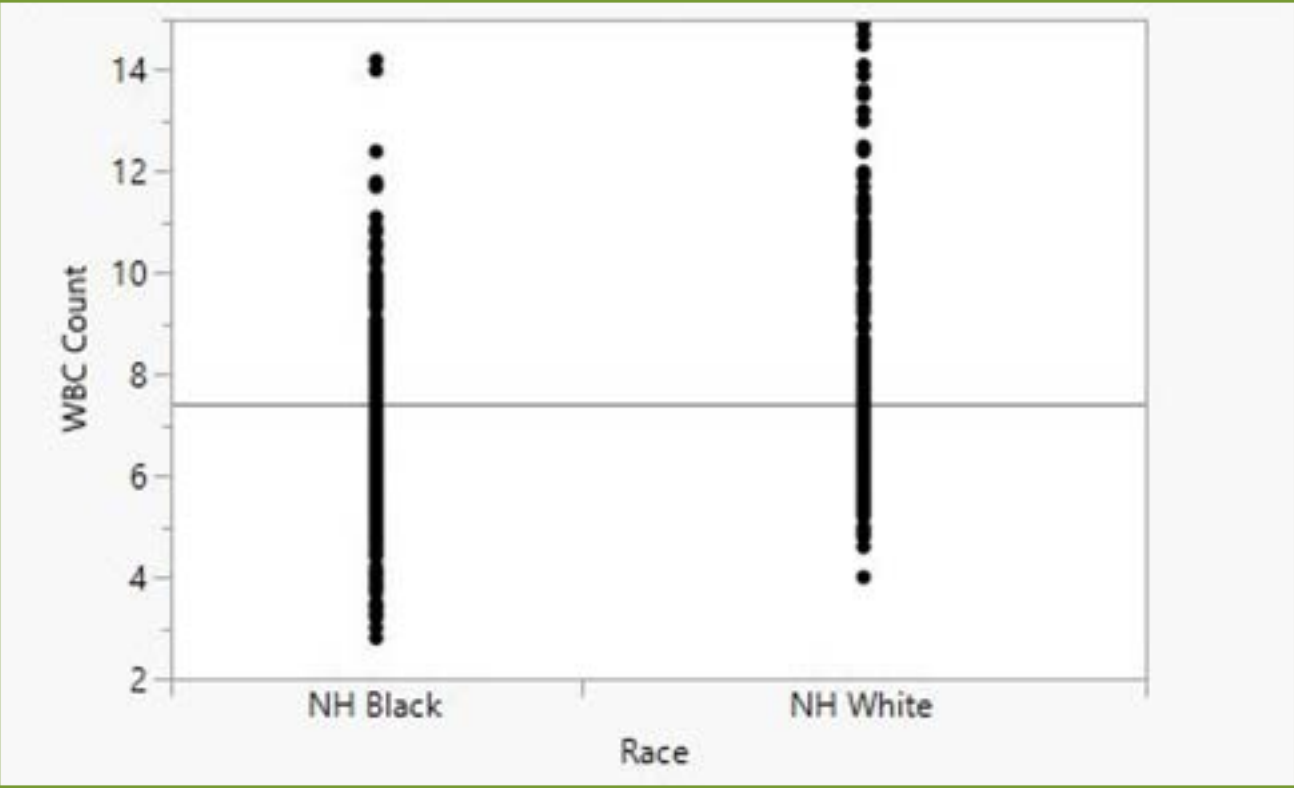
Figure III: Analysis of White Blood Cell Count by Race
Figure III: Shows the comparison of White Blood Cell count by race. This shows that non-Hispanic white women are more likely to have an increased level of WBC count.
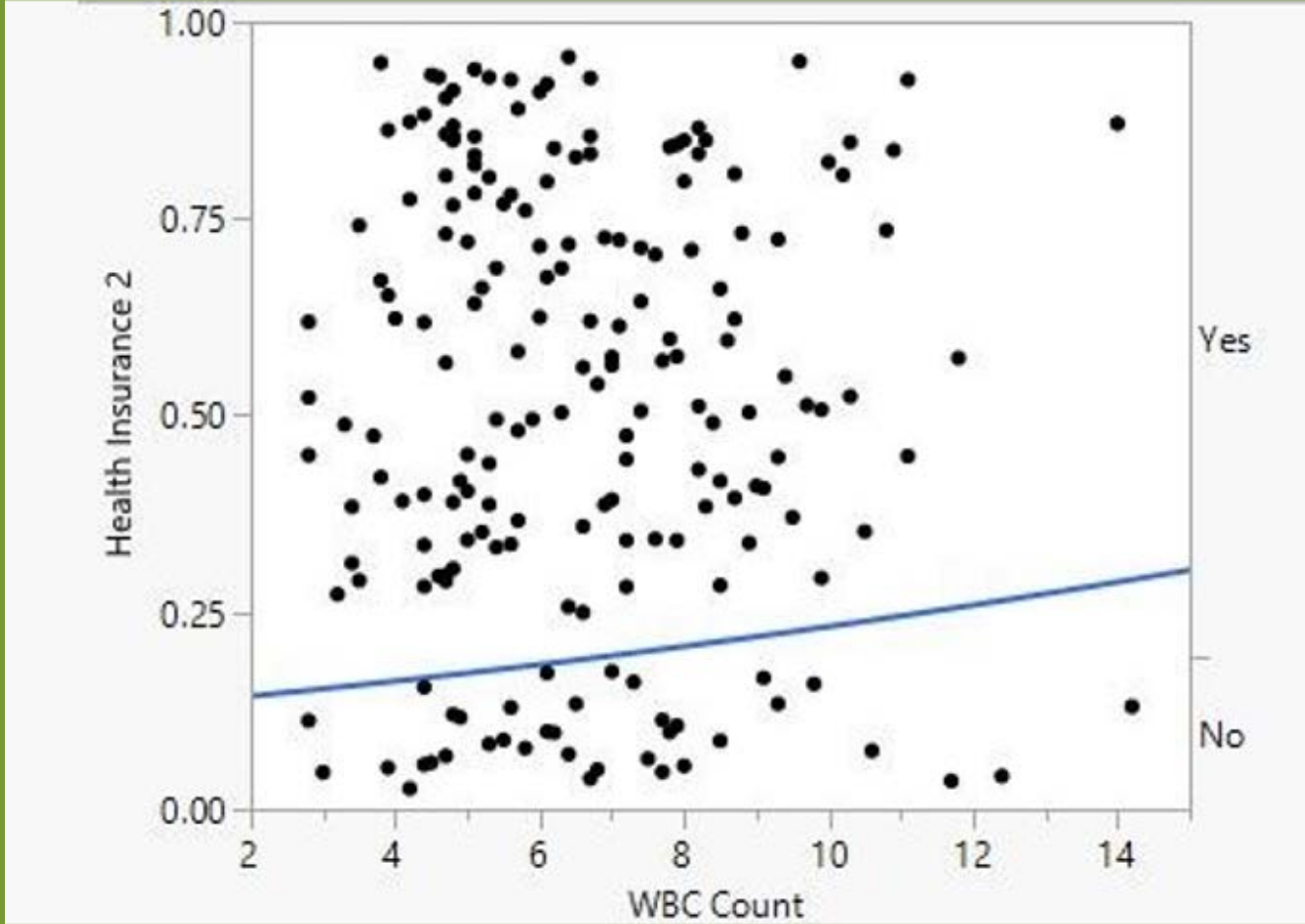

Figure IV: Logistical Analysis of Health Insurance by WBC Count of NH Black Women
Figure IV: This logistical graph shows that there was an inverse correlation between the WBC of Black women and if they had insurance.
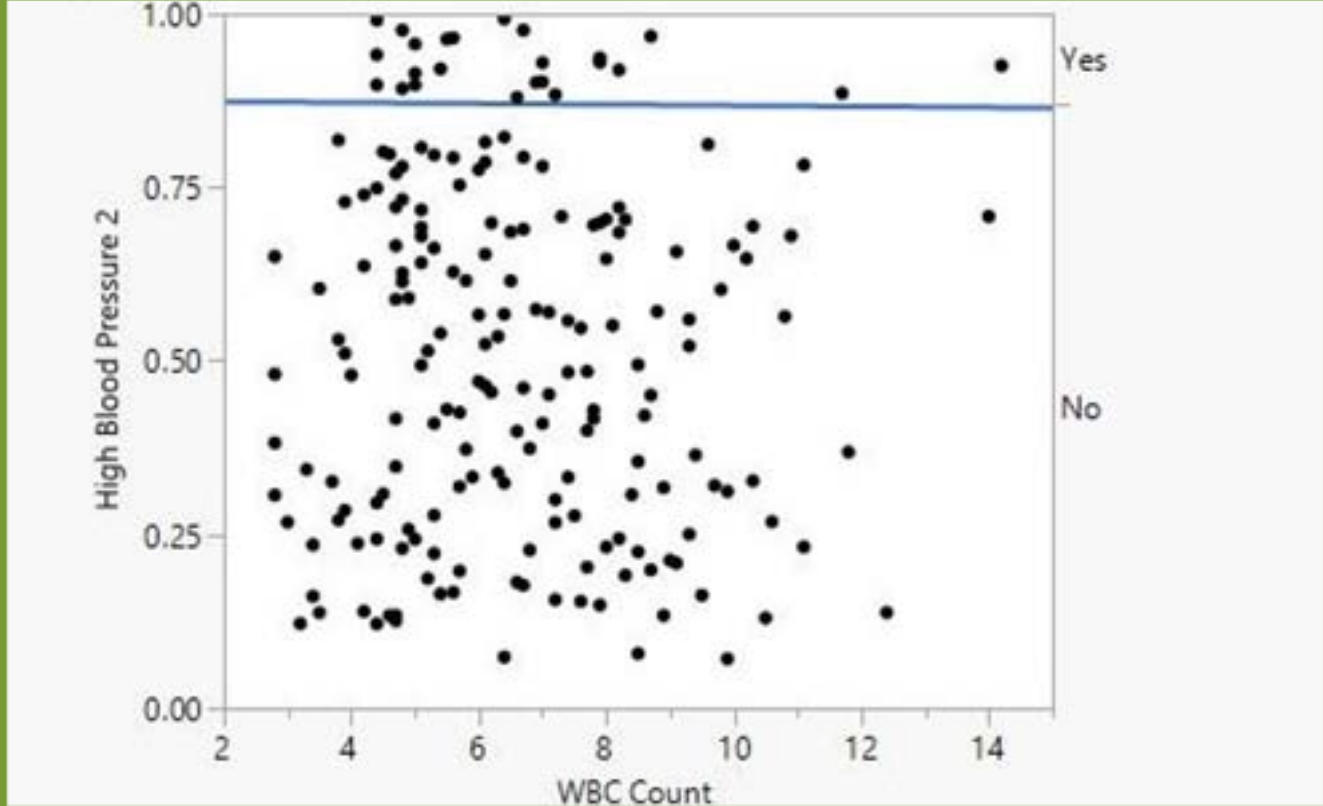

Figure V: Logistic Analysis of High Blood Pressure by WBC Count of NH Black Women
Figure V: Comparison of WBC in relationship with High Blood Pressure of non-Hispanic Black women. This logistic graph shows that when participants responded "Yes" they were documented to having an increased WBC count.

DISCUSSION

Summary

Through our data, we saw a significant relationship between elevated levels of the biological markers of stress—WBC count and creatinine, and high blood pressure—in non-Hispanic Black women. Also, this relationship can be seen with the number of non-Hispanic Black women who do not have health insurance. This relationship shows that these life occurrences are stressful influences on the lives of these women who are in between the ages of 18-40, their prime reproductive years for successful childbearing.

This study can serve as evidence that access to health insurance is a fundamental determinant of a woman's health, especially while pregnant. Access and quality of insurance not only affects the women's health while pregnant but also throughout postpartum as it affects their ability to receive maternal care. The burden of cost from hospital bills for both the infant and mother can be overwhelming and is likely to be a major source of the stress. We can see the effects of this by the increased levels of creatinine in the non-Hispanic

Black women within our sample. Furthermore, we can see how the lack of health insurance and its effect on maternal care is also influential in understanding what separates the United States from other developed nations regarding maternal mortality. Most developed nations have a universal coverage insurance plan that ensures all people have medical care, but the United States insurance system leaves many people without access to care. The data collected within this study supports the idea that the individuals affected most by this are the minority populations, including but not limited to non-Hispanic Black women.

In previous research, it has been stated that Black people have higher rates of creatinine because of the increased muscle mass of Black individuals (Hsu et al., 2008). This is accounted for using the Modification of Diet Renal Disease (MDRD) Study equation. The MDRD Study equation—which includes variables such as age, gender, and race—allows for the observation of chronic kidney disease presence in patients with high creatinine levels ("Estimating Glomerular Filtration Rate", n.d.; Levey et al., 1999). While this equation is widely used, there is still no concrete evidence that race is the deciding factor for why Black people have increased creatinine. However, in other studies—even when rates of creatinine were adjusted for using body weight, age, and gender among other variables—Black people still had significantly higher rates of creatinine. This shows evidence that there are other factors which affect an increased amount of creatinine in Black people, especially in America (Hsu et al., 2008). While we explored the presence of stress as a potential option, and found evidence for this, there are likely several other factors that can also impact this increase of creatinine. With this understanding, it can also be stated that the significant difference between creatinine levels of non-Hispanic Black women to non-Hispanic White women found within this research is supported. However, there is still more research needed to be conducted surrounding this interest, in order to have a more complete understanding of this racial difference, its origin, and how it affects individual's health.

In comparison to existing literature, our study supports most findings on the relationship between maternal stress and poor maternal and infant outcomes. Similar to the Center for Disease Control (CDC) comparative study on pregnancy related mortality ratios (PRMR) in the U.S. across racial groups, we found that access to quality care and control of chronic disease were prevalent factors in analyzing risk (Petersen 2019). Unlike the CDC study, we were unable to control for education in our study but anticipate similar findings: continued disparities across child-bearing age and education levels. We were also unable to control for age specific PRMRs, but existing literature points to the "weathering hypothesis," which posits that Black women's health deteriorates at a faster rate due to chronic psychosocial and economic stress (Petersen 2019, Geronimus 2006). Our study did share similarities with Pike's discussion of the mechanisms that influence maternal stress and thus preterm delivery. Pike found that maternal psychosocial stress would render the intrauterine environment uninhabitable for the fetus, triggering preterm delivery or causing infant mortality. Similarly, we hypothesized that maternal stress was to blame for disparaging mortality rates, and we found that the relationship between our stress indicator and possible stressors (independent variables) were statistically significant.

Overall, we believe that this study showed a great representation of the difference between the health of non-Hispanic White and non-Hispanic Black women in the United States. Through our research, we can see that health is not only an isolated issue pertaining to biomedical standards but also is affected by the socioeconomic status and access to care for many individuals. This can serve as evidence of the importance of social science and ethnographic information when pertaining to an individual's health. Furthermore, this research shows evidence of the several stress factors that can influence

a woman during her prime reproductive years.

Stress can leave terrible effects on the body and negatively impact pregnancy; this research provides evidence for just how numerous those stressors can be. If used in context, medical professionals can work to build a more well-rounded perspective of their patients. By doing this, they can help provide them with resources and the proper care to combat these stressors and ensure a better pregnancy outcome for the mother and infant. We hope that this type of attention to non-Hispanic Black pregnant women will help to lower the rate of maternal and fetal mortality and morbidity in the United States. Therefore, by lowering the maternal and fetal mortality and morbidity rate for non-Hispanic Black women, all other women in this country will also have the ability to experience better care and improved birth outcomes.

1. Why is the maternal mortality rate four times higher for Black Americans than for White Americans?

Limited access to health insurance and healthy food options can be detrimental to a woman's health. Lack of access to health insurance may mean that the ability to have certain genetic testing and testing for biological markers is taken away from the mother. Without this knowledge, the doctor will not be able to provide the necessary preventative measures that could improve their overall health. Therefore, it was important for us to focus mainly on the experiences of women regarding their health throughout their life because it will eventually affect their pregnancies and the health of any infants they may birth. This was accomplished through including women of child-bearing ages regardless of pregnancy history, such as the number of pregnancies or number of children they have. The women within this age group should have the ability to have a successful pregnancy if they choose but also should have the environment to live a healthy life regardless of that personal choice. Furthermore, if they do choose to be pregnant, they should have the information to ensure that they can safely carry an infant in their womb or perform a healthy birth. It is also well known how important diet is for the overall health of an individual. Throughout the United States, many people experience food deserts or areas without access to good-quality food that is available within a reasonable distance. Food deserts are often found in urban areas with large minority populations. Even if these women have the money to eat, it does not mean that the food they consume include the macronutrients necessary to have a viable and healthy pregnancy for their infant (Thurow, 2016). This information shows that while both health insurance and a healthy diet are identified as significant health indicators, in Table II and throughout this paper, they are also the result and impact of socioeconomic factors. Based on this understanding, the maternal mortality rate for Black Americans being four times higher than that of White Americans is a problem that must be addressed by both the medical field and the government. Possible solutions could include:

1. adjusting care for at-risk groups in order to ensure medical risk for infant mortality is lowered,
2. policy that addresses food deserts and negatively impacts companies who prey on urban communities by oversaturating the market with low-quality food options,
3. create policy changes to improve the access to quality health insurance and thus care in heavy minority areas.

These changes not only have the potential to decrease the maternal mortality rate but also to reduce stress and improve the overall health of Black Americans.

II) *What are the factors linking maternal mortality to infant mortality rates in the United States?*

The same factors which impact the maternal mortality rate for Black Americans can also hold true to the significantly high infant mortality rate of Black Americans. Furthermore, the possible solutions are also similar, since the infant mortality reflects both the quality of care that the mother receives before the pregnancy and during the perinatal period. Having insurance and therefore having access to certain testing for the mother is also important for the infant. Without this knowledge, the doctor will not be able to provide the necessary preventative measures that could improve the health of the infant while in the womb. A healthy diet is also important since it is well known how diet can greatly influence the development of an infant. Each of these obstacles can put unnecessary stress on the

infant and the mother. The same solutions stated to address maternal mortality will also lower the infant mortality rate not only for Black women but also for all infants born in the United States.

Limitations

Each of our data points were collected using NHANES; therefore, we were restricted to the information available on this database. This is important to note because while there are better biological measurements of stress, we chose to use the best factors based on what was available to us through NHANES. NHANES only provides certain information as self-reported data and some subjective questions that could influence the data and interfere with the metrics, we chose for our research purposes. An example of this includes the scales for diet, health, and depression. There is no way to ensure the accuracy of the participants' answers to their lifestyles and how they truly compare with other individuals in the study. Another limitation of our research is a reserved number of biological factors for stress. An example of this can be seen through the data for depression. Even though it does not support our hypothesis, this could be a result of the fact that creatinine and WBC are not the only biological marker for stress in the body. There is a possibility that other markers represent the amount of stress, experienced by non-Hispanic Black women, more accurately than creatinine and WBC. Furthermore, research has shown that kidney function, which is the basis for creatinine levels, could be affected by several factors which were not the focus of this research but could be used for extended details in future studies. (Stress and Your Kidneys, 2020).

While we understand that some women may be pregnant outside of the ages of 18-40, and may be affected by similar stressors, we felt that it was necessary to focus on the most common ages to lessen the number of unaccounted factors that may interrupt our data. Based on this information, it was assumed that within these ages women's health would be affected due to stressful events regardless of pregnancy status. However, the health of pregnant women is at a greater risk when experiencing stress because their health is aligned with the health of the fetus.

In the future, we could expand this research by including a greater number of biological factors for stress. Also, we could potentially have a more well-rounded set of questions that allow us to express the individual factors that may be sources of stress that affect our participants' lives.

CONCLUSION

This study provides substantial context into maternal and infant mortality rates between non-Hispanic Black and White Americans by presenting data on stress and health indicators. Our results pose substantial implications for the future of health programming, health policy and research, and obstetric care. We hope that further research considers the dual discrimination that Black women face from racism and sexism, and how a lifetime of discriminatory stress coupled with generational trauma can produce adverse health outcomes for mother and child—making this cyclical. Our significant finding of creatinine being linked to high blood pressure poses an important opportunity for the interception. Prevention strategies to protect against high blood pressure could intercede with the manifestation of stress early on and, thus, is a critical component of culturally competent care. Culturally competent care should also evaluate current measures that can be changed to acknowledge the Black American woman's experience. This study considers stress indicators and multiple health indicators, but it should also be noted that an interdisciplinary study of maternal and child health will assist in understanding American disparities. What may not be explained by biological or genetic reasoning should be looked at through a sociocultural lens, and in this case. Therefore, we recommend looking closer at stress, social experience, and racialization of Black American women and how it can be considered a risk factor for poor maternal and infant outcomes.

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Jewel Tinsley is a graduating senior at UNC-Chapel Hill studying Biology (B.S.) with a minor in Medical Anthropology. The Greensboro, North Carolina native discovered her interest in medical anthropology shortly into her first year at UNC after completing the "Comparative Healing Systems" course. Her lifelong interest in the medical field has bloomed through this broadened understanding of life, science, and medicine through an anthropological lens. Through ANTH 471- Biocultural Perspectives on Maternal and Child Health Jewel and her co-author, Brianna Haliburton, teamed up to complete a cohesive research project that expressed their combined interest in public health and the status of Black women's health within the United States. Outside of the classroom, Jewel has worked as a Resident Advisor, Lead of Internal Relations for the hha! Peer Educators Program, a member of the National Residence Hall Honorary Society of Janus, and a team member of the UNC Women's Club Basketball Team. Also, she served as a student research assistant under Dr. Feng Li, Ph.D. in the UNC School of Medicine Department of Pathology and Lab Medicine studying the pathway of preeclampsia. After graduation, she has plans of continuing her education in pursuit of attending medical school.

Brianna Halliburton is a graduating senior at UNC-Chapel Hill studying Sociology (B.A.) with minors in Health and Society and Medical Anthropology. A Charlotte, North Carolina native, Brianna became interested in studying health equity and health disparities – particularly those facing Black women – after completing "Health and Society" (SOCI 469) at UNC. After learning more about health disparities and studying statistics that were applicable to her own community, Brianna became committed to the field of public health. Biocultural Perspectives on Maternal and Child Health (ANTH 471) allowed for Brianna and her co-author, Jewel Tinsley, to build on their research interests, while also using their skills for specialized research in the field of maternal and child health. In addition to her studies, Brianna is a Research Assistant in the Department of Sociology, under Dr. Katherine Weisshaar, Ph.D. studying race and gender discrimination in the hiring processes - in collaboration with the Indiana University Department of Sociology. Brianna also serves as an Undergraduate Research Assistant in Dr. Megan Roberts', Ph.D. Lab in the Department of Pharmaceutical Outcomes and Policy at the UNC Eshelman School of Pharmacy. She is a member of the research team for the Durham Girls Health Equity Project under Dr. Shauna Cooper, Ph.D. in the UNC Department of Psychology and Neuroscience. Aside from research, Brianna also serves as the Vice President of the UNC section of the National Council of Negro Women (NCNW). After graduation, Brianna will be pursuing her Master of Public Health in Behavioral, Social and Health Education Sciences at the Rollins School of Public Health at Emory University.

The Employment Effects of COVID-19

by Kassia Gibbs & Rashmi Patwardhan

The spread of COVID-19, beginning in 2020 in the United States, has had a widespread economic impact on unemployment rates. This paper aims to investigate the relationship between the spread of the disease and growing unemployment, taking into account geographic location and resulting spatial effects. A fixed effects panel regression model was employed with month and county fixed effects to estimate the impact of COVID-19 on state and county-level unemployment rates. When regression coefficients are scaled for mean cases and deaths in North Carolina, we find that a multiple regression with border county cases and county cases increases the unemployment rate prediction by 0.08 percentage points over a simple regression with only county cases. Similarly, conducting a multiple regression with border county deaths and county deaths increases the unemployment rate prediction by 0.11 percentage points over a simple regression with only county deaths. Our findings reinforce the importance of regional policy in mitigating spatial spillover effects of the pandemic.

Keywords: County-level, COVID-19, Labor Economics, Unemployment, Spatial Effects

INTRODUCTION

Beginning in the United States in 2020, the outbreak of the novel coronavirus (SARS-CoV-2 or COVID-19) has led to mass disruptions in employment and economic development. The rapid spread of the disease has made it unique and especially dangerous. Two months after the first confirmed case, the number of cases in the United States exceeded 100,000. One week later, the number of cases reached 200,000 (Harcourt et al., 2020). This spread has left severe economic effects. The government imposed quarantine measures in response to public health risks, sharply decreasing economic activity in the earliest months of the pandemic. Unemployment rose sharply to 14.7% following the onset of lockdown protocols, the highest rate of national unemployment since December 1940 (U.S. Bureau of Labor Statistics, 2020). Although the country continues to experience surges in cases, some employment recovery has occurred from state re-openings. However, the difficulty of containing the spread and reopening has stilted the process in many areas. This suggests that long-term employment recovery is likely to be uneven from state-to-state and even county-to-county, as varying regional policy impacts both consumer demand and worker willingness to rejoin the workforce. As shown by economic indicators, lockdowns have created marked drops in productivity and consumption. We aim to give more attention to the regional macroeconomic impact of the pandemic, specifically on individual county labor markets. Furthermore, researchers have closely followed swings in both infection and unemployment rates to predict the trajectory of the pandemic and the resulting economic impact it will leave behind. Although the causal link between the pandemic and resulting unemployment is clear, variation on a smaller regional scale has not been investigated as thoroughly. It may also not be obvious, given state-to-state differences in policy, population density, and other local factors. We are contributing to the literature by disaggregating the data and studying county-level effects in greater detail. Moreover, we investigate the role that border effects play on a county's unemployment rates. While the state of affairs in an individual county may dictate its residents' preferences regarding reopening, these effects radiate out in a regional span. Decisions made by actors in a particular county may be based not only on the situation within their county but also by the state of the pandemic in the surrounding counties, which may generate uneven economic impact and infection rates based on proximity. These border effects have the power to influence

household, firm, and government-level decisions. In this paper, we use regression models with region and month fixed effects to illuminate the relative impact of county-level pandemic-related variables, including infection rates in bordering counties, on a given county's unemployment. Greater understanding of these spatial effects allows policy makers to tailor solutions to specific regions, resulting in more effective policy. In the first section, we overview the current body of literature surrounding how the pandemic has affected the economy, as well as spatial effects. We then describe the regression models used and pertinent results in the second section, concluding with our findings: the addition of border effects is beneficial to the analysis of the pandemic's impact on the unemployment rate.

PRIOR LITER

There have been several studies that look at the relationship between measures of economic productivity and health outcomes. In particular, a 2015 study based in China found that a 1% increase in the unemployment rate was associated with an eventual 6.8% increase in mortality (Wang, 2015). Investigating this relationship from the opposite direction will illuminate health and mortality impacts on unemployment rates, and it is especially pertinent during a pandemic.

Prior to the pandemic, the country-wide unemployment rate remained stable and low. Until the pandemic, the national unemployment rate had stayed at or below 4% (U.S. Bureau of Labor Statistics, 2020) since March 2018. This can be explained in part by rising job vacancies and increased consumption, driving demand for goods up and thus increasing company labor demand (Petrosky-Nadeau & Valletta, 2019). Lower unemployment rates followed suit, as new job openings allowed more members of the labor force to become employed. In January 2020, the unemployment rate in the U.S. was 3.6%, the lowest rate in almost 50 years (U.S. Bureau of Labor Statistics, 2020).

Quickly following the onset of the pandemic in the United States, stay-at-home orders caused most non-essential business to come to a halt, decreasing employment, work hours, and

labor force participation (Béland et al., 2020). Even as restrictions gradually lift, areas with higher infection rates appear to be taking a slower path to labor market recovery (Federal Reserve Bank of St. Louis, 2020). Because regional factors such as local industry, population density, and local policy are highly relevant in determining the impact of COVID-19 on unemployment, it is essential that impacts on a regional scale are investigated in order to best tailor policy for both economic and public health improvement.

Regional factors play a significant role in a population's labor market characteristics (Smith & Glauber, 2013) and health outcomes, including mortality rates (Sparks & Sparks, 2009), and will certainly do so in the case of an infectious disease. Mobility across regions can proliferate the spread of infection, further exacerbating any potential risks such as socioeconomic status, access to health and resources, as well as employment (Jarynowski et al., 2020). During the pandemic, spatial factors have become especially relevant with the onset of governmental policy at the state and local levels, creating large-scale effects on employment in the area (Devaraj & Patel, 2020). Stay-in-place orders, as well as reopening restrictions and legal limits on gathering, have worked to decrease the spread of the disease while greatly dampening economic activity. Although these policies are often enacted at the state-level, actual outcomes may be better measured on the county-level, as bordering counties in different states show similar responses to social and economic factors despite state policy differences (Arindrajit et al., 2010). In the case of the coronavirus pandemic, state-level policy may create disparate outcomes for counties, depending on the state they are housed in rather than their immediate surrounding region (Lyu & Wehby, 2020). However, the labor market impacts of COVID-19 are twofold, with supply-side factors, like supply chain disruption, reducing the ability of firms to provide goods and services, while demand-side factors, like individual risk aversion, reduce consumer demand. Paired with lockdown orders affecting both parties, the resulting loss in economic activity cannot be traced to a single policy (Forsythe et al., 2020). Given the variety of factors influencing labor market outcomes, spatial analysis and further investigation of local effects is necessary. Research suggests the usefulness of county data, as it provides a relatively homogeneous sphere of activity and interaction for a population, but counties remain a relevant political and social unit (Thiede & Monnat, 2016). This emerging body of work begins to characterize the relationship between pandemic variables and unemployment rates, suggesting the importance of regional factors and influences. These spatial factors merit further investigation, as they are crucial to the determination of state and local policy as we work to combat pandemic-related harms in the future.

Data

The data for unemployment rates, including adjusted unemployment rates, comes from the Bureau of Labor Statistics. These were collected on a county-by-county and state-by-state basis in order to facilitate analysis at different geographic scales. Two datasets were compiled with the most current data at the time of writing, with one beginning in November 2019 and including data until June 2020 and the other with additional preliminary data from July 2020.

COVID-19 case information was also obtained on a county-by-county and state-by-state basis from the CDC's online reporting data source, USA Facts. End of month cumulative cases, deaths, and test counts were used. County and state-level unemployment data were collected from the Bureau of Labor Statistics. End of month cumulative testing data on a state-by-state basis were obtained from The Atlantic's COVID Tracking Project.

COVID-19 tracking data for case and death counts were not available corresponding to all available unemployment data, leading to the removal of US territory data including Puerto Rico, Guam, Virgin Islands, American Samoa, and Northern Mariana. Case reporting of United States COVID-19 cases before January 2020 was not widely available, and the relative inactivity of the pandemic allowed for the assumption of zero cases and deaths until data was made available for these metrics, starting in January. Reliable test tracking on a state-by-state basis became available in March, restricting statewide testing analysis on unemployment statistics to

the months of March-June.

The data samples used begin in November 2019 to establish baseline conditions pre-pandemic. The state-level data sample included a total of 408 observations, split equally between observations before and after the onset of the pandemic. County-level data included 25,128 observations, with 12,564 observations before March 2020 and an equal number during the pandemic thus far. In North Carolina, the total of 800 observations were also split equally between data from before the pandemic and data during the pandemic.

Measuring the economic impact of COVID-19 is complex for various reasons. Most notable among these is the rapidly changing state of the pandemic as we experience it in the present. We can make attempts to mitigate these problems by looking at a snapshot in time (Ataguba, 2020). For that reason, this paper focuses on COVID-19 cases up until June 30, 2020. Because of the continuously emerging quality of the data, not all adjustments that will be made are reflected in the information used.

Descriptive statistics help to characterize both the pandemic and movement within the labor market. Because the pandemic became active and widespread in the United States in March, related variables are described from March to June in order to provide the most relevant context and to prevent low values in the first half of the time frame skewing averages.

Table 1.1: Descriptive Statistics, Pandemic Variables			
March 2020 − June 2020			
	Mean	Maximum	Standard Deviation
State			
Monthly Cases	27,686.11	393,496	54010.77
Monthly Deaths	1,434.368	31,625	3,805.251
Monthly Tests	276,201.7	4,167,139	521,687
County			
Monthly Cases	446.335	103,529	2,809.253
Monthly Deaths	23.283	7,103	200.521
NC County			
Monthly Cases	259.59	11,170	746.915
Border Cases	1,673.405	15,712	2,543.482
Monthly Deaths	6.485	146	14.426
Border Deaths	41.795	265	53.592

Table 1.2: Descriptive Statistics, Unemployment Rate						
	November 2019 − February 2020			March 2020 − June 2020		
	Mean	Maximum	Std. Dev	Mean	Maximum	Std. Dev
Monthly State UR%	3.55	6.1	0.846	10.127	30.1	4.977
Monthly County UR%	4.136	21.2	1.842	9.016	41	4.772
Monthly NC County UR%	4.147	14.4	1.254	9.053	24.1	3.752

COVID-19 cases and deaths on a state and county-level basis exhibited a pattern consistent with exponentially increasing cases throughout the United States. Unemployment rates by county and state prior to pandemic-related changes were close to 4%, but they rose to a county-level and state-level maximum of 41% and 30.1%, respectively. Unemployment rates in North Carolina were comparable to county-level averages, with a mean of 4.147% prior to the pandemic and a mean of 9.053% during the pandemic.

Effect of Statewide Cases on Statewide Unemployment Rate

Both in the case of lockdowns and re-openings, state policymakers have led the way in the administration of COVID-19 public health measures. The lack of a unified federal policy regarding containment measures suggests that a state-level breakdown may be a useful starting point in the spatial analysis of the pandemic's effects on unemployment. The use of a fixed effect regression model allowed us to control for invariant factors within months and invariant factors within states. The fixed effect for each month captured variables unique to that particular month, such as seasonal economic activity, while the fixed effect for each state captured variables unique to the state,

including important metrics such as population and industrial and political makeup. These effects are unlikely to significantly shift over the time frame of analysis.

The regression model with fixed effects and robust standard errors for state-by-state data can be described as follows:

$$UR_{i,t}^{s} = \alpha_i + \alpha_t + \beta C_{i,t}^{s} + \varepsilon_{i,t} \tag{1}$$

Here, $UR_{i,ts}$ represents the U3 unemployment rate in a particular state at time t. The i term is a state fixed effect, and t is a month fixed effect. The coefficient describes the change in the unemployment rate for each unit change in $C_{i,ts}$, which represents cases in a particular state and month.

Table 2. State Regression Results

Monthly UR%	(1)	(2)	(3)
State Cases	1.72 $*10^{-5}$ ***		
	(3.51$*10^{-6}$)		
State Deaths		2.54$*10^{-4}$ ***	
		(0.000)	
State Tests			1.79$*10^{-6}$***
			(2.72$*10^{-7}$)
Observations	408	408	408
R-squared	0.864	0.866	0.864

Robust standard errors are reported in parentheses. All regressions include state and month fixed effects.

***p<0.01, **p<0.05, *p<0.1

Column 1 of Table 2 quantifies the impact of each additional case on a state's unemployment rate. This coefficient is best understood in the context of mean cases after the onset of the pandemic, 27,686, which predict an increase of approximately 0.48 percentage points in the unemployment rate. At the maximum statewide case count, 393,496, the model predicts an increase of 6.77 percentage points in the unemployment rate. It is important to consider that early in the progression of the pandemic, many states had reached a number of cases at or greater than the mean value of cases, and the number of cases in most states continues to increase in the present. As a result, future data points are highly likely to show higher maximum values and thus higher impacts on unemployment rate. Using a statewide average close to 4% prior to the pandemic, this would suggest an increase to 11% unemployment, indicating that the unemployment rate more than doubled.

Measuring the severity of the pandemic's spread and resulting economic impact may be better handled by the number of deaths reported by a state, as this outcome records the most severe cases. In order to investigate this possibility, the model utilizing the statewide effect of pandemic-related deaths on the unemployment rate was developed and can be represented as follows: variables remain the same as in equation 1 with the exception of $D_{i,ts}$, which represents statewide deaths in a particular state and month.

$$UR_{i,t}^{s} = \alpha_i + \alpha_t + \beta D_{i,t}^{s} + \varepsilon_{i,t} \tag{2}$$

Column 2 of Table 2 shows that each death had more than ten times the effect on the unemployment rate as each case, but given the lower number of deaths relative to cases, this impact on the unemployment rate is comparable to that of cases. In particular, 1,434 mean deaths during the pandemic correspond to an increase of 0.36 percentage points in the unemployment rate. At its maximum, a state death count of 31,625 predicts an increase of 8.05 percentage points in the unemployment rate. Larger death counts may indicate the severity of COVID-19 spread in certain areas and may lead to greater caution, taken either by the state itself or by individual citizens within it. As a result, self-isolation and subsequent lack of consumer spending may lead to greater joblessness and higher unemployment rates, potentially explaining the size of relative

effects. However, the smaller number of deaths by state balances the magnitude of the coefficient.

An additional variable that may represent the reach and severity of the pandemic is testing. The model relating statewide test counts with unemployment rate uses the variable $T_{i,ts}$, representing the number of tests administered in a particular state and month; all other variables are unchanged from Equation 1:

$$UR_{i,t}^{s} = \alpha_i + \alpha_t + \beta T_{i,t}^{s} + \varepsilon_{i,t} \tag{3}$$

Column 3 of Table 2 quantifies the impact of each test on the unemployment rate. The mean number of tests conducted, 276,202, would correspond to an increase of 0.49 percentage points in the unemployment rate, and the maximum number of tests, 4,167,139, corresponds to an increase of 7.46 percentage points in unemployment. Although tests are broadly conducted and rarely found to be predominantly positive at any region size, the economic impact on the unemployment rate predicted by the model utilizing tests was not starkly different from those using cases and deaths, which may initially appear to be better measures of severity.

Statewide cases, deaths, and tests had a statistically significant effect on the state-level unemployment rate at the 99% level, and the R-squared value across all models was approximately 0.86. In economic terms, the scales of unemployment changes caused by these three pandemic variables are very similar, suggesting that all three may be used as metrics to gauge the severity of the pandemic. While the coefficients are not equal in magnitude, the corresponding case, death, and test counts appear to balance these differences in practical terms.

Effect of County Cases on county-level Unemployment Rate

State-level policy may inform general decisions made by a state's residents, but local political climate and circumstances are likely to vary within states, and mobility is more common in a smaller physical radius. Given the relevance of counties as spatial and political units, local analysis provides a closer look at regional pandemic impacts on unemployment rates. Narrowing in on the county-level, a similar regression model with fixed effects and robust standard errors was used to estimate the effect of county pandemic variables on the county unemployment rate. This model is characterized as follows:

$$UR_{i,t}^{c} = \alpha_i + \alpha_t + \beta C_{i,t}^{c} + \varepsilon_{i,t} \tag{4}$$

In this model, $UR_{i,tc}$ represents the U3 unemployment rate in a particular county and month. The county and month fixed effects are represented by i and t, respectively. The coefficient describes the change in unemployment rate for each unit change in $C_{i,tc}$, which represents cases in a particular county and month. Given state results, we can expect that county impacts on unemployment rates will follow a similar pattern in terms of the relative effect of additional cases and deaths. If both cases and deaths tend to be similar representatives of the pandemic's severity and related economic impact, this should hold at a smaller regional level as well.

Table 3. County Regression Results

Monthly UR%	(1)	(2)
County Cases	2.36 $*10^{-4}$ ***	
	(2.28$*10^{-6}$)	
County Deaths		0.00323***
		(2.61 $*10^{-4}$)
Observations	25,128	25,128
R-squared	0.791	0.791

Robust standard errors are reported in parentheses. All regressions include state and month fixed effects.

***p<0.01, **p<0.05, *p<0.1

Column 1 in Table 3 shows the percentage point increase in county unemployment rate for each additional case. To scale, the mean number of cases during the pandemic by county, 446, is associated with an increase of 0.11 percentage points in the unemployment rate. The maximum number of cases by county, 103,529, predicts a percentage point increase of 24.39 in the unemployment rate. This increase of 6.57 to the county average employment rate represents a final rate of 30.96.

Countywide death tolls were also used to predict the unemployment rate in that county with the following model, where variables remain the same as in equation 4 with the exception of $D_{i,tc}$, which represents the number of deaths in a county and month.

$$UR_{i,t}{}^c = \alpha_i + \alpha_t + \beta D_{i,t}{}^c + \varepsilon_{i,t} \tag{5}$$

The mean number of deaths by county during the pandemic, 23, is associated with an increase of 0.07 percentage points in the unemployment rate given the results in Column 2 of Table 3, while the maximum number of deaths by county, 7,103, is associated with a 22.96 percentage point increase.

Both coefficients were statistically significant at the 99% level, with an R-squared value of about 0.79 across models. Unlike state-level analysis, the maximum number of deaths in a county predicted a smaller increase in the unemployment rate, further providing evidence to support the idea that both cases and deaths may serve as equivalent metrics of pandemic severity. In addition, mean case and death counts predict very low shifts in the unemployment rate for that county. At the maximum values of these variables thus far, however, the predicted impact is much greater than that observed for states. This may be partially explained by the greater variation in county data, as many counties have seen few cases and even fewer deaths. In those areas, the initial onset of the pandemic may have created less comparative unrest and economic upheaval, while heavily populated regions, or those with economies largely dependent on service related industries, may have seen sharp spikes in unemployment.

Effect of County Border Cases on County Unemployment Rate

Economic outcomes within a county are certainly based on individualized county factors, but they are also affected by thoroughfare and surrounding circumstances. Due to smaller physical size and ease of mobility between counties, neighboring areas' futures are often linked. Higher case and death figures may become less relevant to local unemployment as they move farther away in physical distance, so it is likely that within-county variables will predict larger shifts in the unemployment rate in comparison to external county variables. However, cross-county travel and potential infectious spread are likely to play a role as well, meaning border county cases and deaths will likely be associated with an increase in unemployment rates and potentially with higher total prediction values.

In order to investigate these effects in greater detail in North Carolina, we first employed a simple regression model with county and month fixed effects and robust standard errors in order to set up a comparison to border effects, as follows:

$$UR_{i,t}{}^{NC} = \alpha_i + \alpha_t + \beta C_{i,t}{}^{NC} + \varepsilon_{i,t} \tag{6}$$

$UR_{i,t}NC$ is equal to the U3 unemployment rate in a particular month and North Carolina county. As in the previous models, 1 and 2 represent the fixed effects of county and month, respectively. Coefficient 1 represents a county's change in unemployment rate for every unit change in its monthly cases.
The following model for deaths within North Carolina counties was set up identically to Equation 6 with the sole exception of variable $D_{i,t}NC$, now representing deaths rather than cases.

$$UR_{i,t}{}^{NC} = \alpha_i + \alpha_t + \beta D_{i,t}{}^{NC} + \varepsilon_{i,t} \tag{7}$$

Table 4. Bordering Regression Results

Monthly UR%	(1)	(2)	(3)	(4)
County Cases	$3.09 *10^{-4}$ ***		$2.63 *10^{-4}$ ***	
	$(9.9*10^{-5})$		$(8.24*10^{-5})$	
County Border Cases			$5.76*10^{-5}$ **	
			$(2.61 *10^{-5})$	
County Deaths		0.024***		0.021***
		(0.004)		(0.004)
County Border Deaths				0.003**
				(0.001)
Observations	800	800	800	800
R-squared	0.890	0.891	0.890	0.891

Robust standard errors are reported in parentheses. All regressions include state and month fixed effects.

***p<0.01, **p<0.05, *p<0.1

In Columns 1 and 2 of Table 4, it is shown that coefficients in North Carolina are similar in magnitude to those seen between counties around the United States. We then expanded Equation 6 to incorporate border cases with a multiple regression model with county and month fixed effects and robust standard errors. This model was set up as follows:

$$UR_{i,t}{}^{NC} = \alpha_i + \alpha_t + \beta_1 C_{i,t}{}^{NC} + \beta_2 BC_{i,t}{}^{NC} + \varepsilon_{i,t} \tag{8}$$

Most variables remain the same as in Equations 6 and 7 with the exception of 2, which represents the change in county unemployment rate with every unit change in the sum of all cases in border counties, represented by $BC_{i,t}NC$.

Because North Carolina's county mean and maximum number of cases and deaths are lower than the mean and maximum values among counties throughout the United States, coefficients of similar magnitude will create smaller practical effects when scaled compared to those seen for countrywide county-level data. Column 3 of Table 4 reports the impacts on unemployment rate of both county cases and county border cases. As expected, the magnitude of impact is higher on unemployment rates of each additional case or death within one county in comparison to the impact of each additional case or death in a border county. Given the mean number of cases during the pandemic in North Carolina counties, approximately 260, the model predicts the unemployment rate within that county should increase by 0.068 percentage points. The maximum predicted impact on the unemployment rate is an increase of 2.94 percentage points, at 11,170 cases. As for the average of border cases, column 3 in Table 4 predicts a 0.096 percentage point increase in the unemployment rate, with a maximum increase of 0.905 at 15,712 border cases. Adding border cases may not have greatly modified the coefficients of within-county cases, but it does affect overall unemployment predictions. These predicted effects are modestly larger than those predicted by the model that estimates the unemployment rate utilizing only North Carolina county cases. In total, the simple regression model predicted an increase of 0.08 percentage points in the unemployment rate for mean cases, while the multiple regression model predicted an increase of 0.164 percentage points. For maximum cases, the simple regression model predicted an increase of 3.45 percentage points, while the multiple regression model predicted an increase of 3.85.

The multiple regression model using both within county deaths and border county deaths is written as follows, with variable definitions unchanged from Equation 8 except $D_{i,t}NC$ and $BD_{i,t}NC$, which represent death counts and border death counts in a particular county and month, respectively.

$$UR_{i,t}{}^{NC} = \alpha_i + \alpha_t + \beta_1 D_{i,t}{}^{NC} + \beta_2 BD_{i,t}{}^{NC} + \varepsilon_{i,t} \tag{9}$$

multicollinearity with cases and deaths, the weak relationships between these variables were verified by a variance inflation factor below five, which indicates that cases and deaths within a county do not demonstrate a collinear relationship with border county cases and border county deaths.

Per the results in column 4 of Table 4, the mean number of deaths and border deaths both individually predict an increase of 0.126 percentage points in the unemployment rate. The predicted effect using maximum deaths and maximum border deaths is an increase of 3.07 and 0.795 percentage points

respectively. In total, the simple regression model predicted an increase of 0.144 percentage points in the unemployment rate for mean deaths, while the multiple regression model predicted an increase of 0.252 percentage points. For the maximum death count, the simple regression model predicted an increase of 3.504 percentage points, while the multiple regression model predicted an increase of 3.865. Each coefficient was statistically significant at the 95% level, with an R-squared value of approximately 0.89 for both models.

Examining an individual county illustrates the predictive accuracy of the model and provides further context for the effects to scale. In Orange County, for example, the unemployment rate in January was 3.2% before the beginning of the pandemic. By the end of June, Orange county reported 669 cases, and border counties reported a total of 5,986 cases. The model predicts an unemployment rate increase from 0.521 percentage points to about 3.721%. Similarly, Orange County reported 41 total deaths in June, and border counties reported a total of 143 deaths. The model predicts an unemployment rate increase from 1.29 percentage points to 4.49%. The actual unemployment rate of 5.9% at the end of June was underestimated by the model but fell closer to the rate predicted by the number of deaths and border deaths. Because the multiple regression model consistently predicts a higher level of unemployment than the simple regression model, it begins to close the underestimation gap. Accounting for border cases seems to increase the accuracy of the prediction.

Overall, the data shows that a lack of virus containment in surrounding areas is related to greater economic damage within a county unit, although less so than a lack of containment within the county itself. High levels of mobility between counties may explain the importance of larger regional area containment to alleviating growing unemployment. The size of these spillover effects illustrates the importance of regional and even state-level policy, as county units, if able to safely contain the spread of COVID-19, have the potential to support recovery in neighboring counties.

CONCLUSION

In this paper, we analyzed the effect of various pandemic-related variables on unemployment rates at the state level, country level, and county level within North Carolina. We used fixed effects panel regression models with data ranging from November 2019 to June 2020. At both the state and county levels, we find that deaths and cases are comparable predictors of unemployment rate changes, and may be equivalent indicators of pandemic severity. We focused on the spatial effects on North Carolina county unemployment rates created by cases and deaths in border counties, finding that multiple regression models utilizing border sums consistently increase unemployment rate predictions and raise predictive accuracy. The multiple regression model with cases and border cases predicts an unemployment rate that is 0.08 percentage points higher than the simple regression model scaled for mean cases, and 0.4 percentage points higher scaled for maximum cases. The multiple regression model with deaths and border deaths predicts an unemployment rate that is 0.11 percentage points higher than the simple regression model scaled for mean deaths, and 0.365 percentage points higher scaled for maximum deaths. These results point to the relevance of geographic location to pandemic spread, and suggest the importance of containment measures in regional units. In line with previous findings, each county's policy and resulting crowd dynamics, including mobility, are associated with their bordering county's infection rates and unemployment rates, highlighting the importance of unified regional policy. Reducing spillover effects and containing the spread of COVID-19 may be associated with positive economic outcomes not only for a particular local area, but communities surrounding it as well.

To further this work, a wider dataset including county-level information for every state in the United States would be beneficial. Around the world, spatial units comparable to counties may also provide crucial insight into the differences among global regions in virus containment, mobility based spread, and resulting economic impact. As the pandemic continues to spread around the United States, time series modeling with a longer panel of data may provide

additional insight into the economic impact of a "wave" and recovery times for reopening states. In addition, as cases mount, nonlinear effects may be observed if additional cases create diminishing economic impacts. Finally, event studies evaluating the impact of local and state policy decisions can help account for unprecedented unemployment rates and provide a greater basis for effective policy that helps a community and its neighbors move toward a healthy and economically productive future.

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APPENDIX A: Descriptive Statistics with Preliminary Data

Table 1.3: Descriptive Statistics, U.S. Counties

November 2019 – July 2020 (p)

	Mean	Maximum	Standard Deviation
Monthly Cases	357.3122	188481	2889.633
Monthly Deaths	15.711	7247	165.626
Monthly UR%	6.729	41	4.268

Table 1.4: Descriptive Statistics, North Carolina

November 2019 – July 2020 (p)

	Mean	Maximum	Standard Deviation
Monthly Cases	251.091	20502	1016.74
Bordering Cases	1637.371	29462	3733.978
Monthly Deaths	5.018	199	15.052
Bordering Deaths	32.95	392	62.868
Monthly UR%	6.816	24.1	3.595

APPENDIX B: Regression Results With Preliminary Data

Table 5: County Regression Results, Nov 2019 – July 2020 (p)

Monthly UR%	(1)	(2)
County Cases	$1.57 * 10^{-4}$ ***	
	$(2.26 * 10^{-6})$	
County Deaths		0.00323***
		$(2.05 * 10^{-4})$
Observations	28,268	28,268
R-squared	0.784	0.786

Robust standard errors are reported in parentheses. All regressions include state and month fixed effects.

***$p<0.01$, **$p<0.05$, *$p<0.1$

Table 6: Bordering Case Regression Results, Nov 2019 – July 2020 (p)

Monthly UR%	(1)	(2)
County Cases	$1.52 * 10^{-4}$ ***	
	$(4.73 * 10^{-5})$	
County Border Cases	$3.30 * 10^{-5}$ **	
	$(1.37 * 10^{-6})$	
County Deaths		0.017***
		(0.003)
County Border Deaths		0.003***
		(0.001)
Observations	900	900
R-squared	0.886	0.888

Robust standard errors are reported in parentheses. All regressions include state and month fixed effects.

***$p<0.01$, **$p<0.05$, *$p<0.1$

About the Authors

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How Do Fox News and CNN Portray Russia's 2016 Election Interference? An In-Depth Look at Gatekeeping and Tone Bias

by Collins K. Alexander

The United States faces a great political divide today. Foreign adversaries seek to wage domestic division to their benefit, threatening American national security. Non-partisan intelligence agencies and other apolitical organizations concluded that the Russian government undertook an extensive campaign of interference to sway the 2016 U.S. presidential election. So why are Americans divided on the issue? In order to effectively understand why Americans have become increasingly split in recent years, especially pertaining to Russian election meddling, it is crucial to examine institutional information sources: news networks. This work seeks to examine media bias among cable news as coverage pertained to Russian interference in the 2016 election. Furthermore, this work explores what occurred during the 2016 election, the history of election interference dating back to the Cold War, and an evaluation of the current American news environment as factors contributing to media bias in cable news coverage of the issue. The research entailed a self-designed study of compiling a database of transcripts from CNN and Fox News, two major sources of information among wide demographic groups, from a three-year span and logging dates and keywords to measure gatekeeping and tone biases. Several hypotheses were tested to illuminate different ways of viewing biases. Long-term consumption to the messages of one network, or one political group, is responsible for entrenching one's beliefs to their preexisting preference, worsening political division in the United States, and exacerbating national security concerns.

Keywords: 2016 election, Russia, interference, bias, cable news

INTRODUCTION

The United States Office of the Director of National Intelligence (ODNI) released a major report detailing Russian operations to affect the outcome of the 2016 presidential election on January 6, 2017. That night, Sean Hannity, a TV host for Fox News Channel, declared that "the only reason President Obama and the Democrats care now about cybersecurity is because they need an excuse to explain why Hillary Clinton lost." He further stressed how Russia never tampered with votes. [1] Viewers of CNN that night heard Anderson Cooper state that "Putin ordered influenced (sic) the campaign including cyber attacks to hurt Hillary Clinton and help Donald Trump." [2]

Hannity alleged that the report was politically charged and doubted that Russia intentionally helped Trump, meaning his victory was still integrous. Cooper acknowledged that no votes were altered, but emphasized that Trump strategically downplayed the intelligence report's findings. The emphases and omissions in these two political commentaries on January 6, 2017 exemplify the trend of CNN and Fox News coverage of Russian interference in the 2016 election. This contrast is an alarming characteristic of cable news and contemporary media overall.

Media bias is of critical importance to U.S. national security. The evident varying messages of the American press expose the electorate to contradictory and extreme viewpoints. As a result,

Americans are susceptible to widening divides in values, beliefs, and policies on which must be compromised for effective democratic governance. The topic of Russian election meddling in 2016 is narrow, but the study of media bias on the issue illuminates wider issues in common media practices and exposure to opposing beliefs, which are critical for effectively countering foreign influence operations.

Russian election interference itself is a divisive, unique, and momentous issue. Donald Trump, whose everyday rhetoric contributes to disunity, is a central character. On top of extreme statements and insult politics, throughout his term, President Trump has consistently doubted or even denied that Russia interfered in the election. He publicly downplayed the fact that Russia interfered after speaking to Putin in July 2018 and frequently tweeted phrases like "no collusion," "no obstruction," and "hoax" which "introduces dissonance in the electorate" and encourages his supporters to follow his example.[3]

Challenging reputable intelligence conclusions fuels doubt about the validity of the U.S. election system, which, in turn, threatens democracy. Suffrage is a principal American value granting individuals the ability to decide their representatives. Election tampering undermines the people, thereby harming

collective American society. To foreign states, this subversion is a symbolic indication of weakness. As a country whose global presence historically and currently rests on championing democracy, the U.S. ought to be a robust model. The democratic system as a whole is at stake.

Russian election meddling also pitted national security and domestic politics against one another. Nothing better exemplifies this idea than the way Senate Majority Leader Mitch McConnell responded to grave intelligence warnings in the summer of 2016. According to then-CIA Director John Brennan, McConnell questioned the intelligence's integrity and implied that the CIA was trying to prevent Trump from winning. [4] The zero-sum attitude of President Trump provides another example. A former senior adviser to Trump stated that it was impossible to brief the president on Russian election meddling without him interpreting it as a dispute of his legitimacy. [5] Together, Trump's centrality, the symbolism of U.S. elections, and national security concerns make it difficult for a middle ground to form.

There is a severe lack of urgency in improving the country's ability to combat foreign meddling. Though the impact of Russia's actions is nearly impossible to measure, it might embolden them to invest in more complex and effective efforts, as the CIA did after helping the Christian Democratic party win monumental Italian elections in 1948. [6] Studying media bias on Russia interference may reveal trends applicable to reducing the effectiveness of foreign actions.

This work analyzes volume and tone in prime time shows, between 8 and 11 PM Eastern Standard Time on weeknights, from Fox News and CNN. The study is a compilation of all transcripts referring to Russian interference or subsequent investigations between May 1, 2016 and April 30, 2019 with tallies of episodes referring to a list of keywords and phrases. The overarching question intended to be addressed is: *How did CNN and Fox News portray Russian interference in the 2016 election?* More specifically, *Did Fox and CNN display gatekeeping bias? Did Fox and CNN display tone bias*? Varied mentions of keywords indicate that CNN and Fox emphasized different aspects of Russian interference, suggesting that there was tone bias by both networks. The data shows some signs of gatekeeping bias on the part of both CNN and Fox, but further analysis is required to definitely conclude this.

This work begins with an explanation of Russian interference in the 2016 presidential election as established by U.S. intelligence reports and non-partisan sources. It then discusses the American media environment today before linking the two with how the media reported on 2016 meddling. A description of and results from original research about CNN and Fox News coverage from a three-year period follows. Finally, conclusions are drawn about the national security implications and possible further research.

BACKGROUND

To clarify terms used in this work, it is necessary to begin with definitions. Election "interference" shall refer to a general action to alter what would otherwise be a natural outcome. "Meddling" is similar to "interference," though its connotation is more indirect. In literature, "influence" refers to overt, through state media outlets, and covert, through paid social media trolls, efforts to shape public opinion. "Influence," "interference," and "meddling" are the three main terms used to refer to Russian efforts to impact the 2016 election. The methodology section revisits these definitions later.

In order to contextualize the events of 2016, two points are crucial to understand. First, election interference is not new. The Committee for State Security (KGB) and Central Intelligence Agency (CIA) have rich pasts of election interference. During the Cold War, the KGB bribed journalists, funded candidates, bankrolled media outlets, and disseminated disinformation. [7] It meddled in various U.S. elections between 1960 and 1984 but had very little impact. [8] The CIA applied economic pressure, covert military action, forged notes, spread propaganda, and funded candidates and organizations. [9] Most CIA efforts have historically focused on influencing voters with messaging, rather than altering voters themselves. [10] Information manipulation is a key tactic, especially nowadays when the means of finding information are at our fingertips. The second point is that Russia has revamped its information operations across the world, especially in the traditional

Soviet sphere of influence. [11] Russian election meddling is not unique to the U.S., nor is it a recent phenomenon.

2016 INTERFERENCE

According to official U.S. intelligence community reports, the Russian government meddled in the 2016 election. It did so in three ways. Hackers conducted cyberattacks on American political organizations and released the information to the public. Russia's Main Intelligence Directorate (GRU) gained access to private data of the Democratic National Committee, Democratic Congressional Campaign Committee, Clinton Campaign Chairman John Podesta, and other Clinton staffers. [12] It then publicized documents and emails through the fake "DCLeaks" and "Guccifer 2.0" accounts and WikiLeaks. [13]

Hackers also targeted the voter registration systems of 21 states, breaching those of Illinois and Arizona. [14] There is no evidence that they changed or deleted data, but the demonstrated vulnerability undermines public confidence in elections. [15]

The Russian government and its proxies disseminated propaganda via state-sponsored media and on social media. RT and Sputnik, supported by the Russian government, blended true information with skewed and false information in English on the internet and TV. [16] Workers from the Internet Research Agency (IRA), a "troll farm" where people created false online personas, generated and spread disinformation and divisive content on contentious themes, such as black culture, gun policy, and illegal immigration. [17] Russia's overarching goals were to harm Clinton's electability, help Trump's electability, and overall undermine the American public's confidence in the election. [18]

THE MEDIA

A recent Pew survey found 74% of Democrats believe Trump benefited from Russian meddling in 2016, while 75% of Republicans believe neither side benefited. [19] Pew's data offers an idea of how politically fragmented the beliefs of Americans are in regard to Russian interference. The degree of partisan division invites the question of why two immense segments of the population are so consistent in their beliefs. This inquiry requires a deeper examination of information sources: America's media environment.

Government and economic principles, technological developments, and bias explain current media trends and practices. Democracy is the foundation upon which news outlets operate. The First Amendment of the U.S. Constitution guarantees the freedom of speech and the press. This presents a stark contrast to totalitarian nations, where governments dictate what the media can express. By controlling information sources and content, the government shapes what people believe. For example, most Russian TV channels are state-controlled, giving the Kremlin "an almost unlimited monopoly" of influencing Russians. [20] In contrast, the American media is free to decide what topics to discuss and how to characterize them.

The free market dictates many facets of the American media. It is effectively controlled by consumers, who collectively decide if an outlet should continue producing news through financial support. A related theory is political entrepreneurs' use of the political information sphere to garner support for their preferred agenda and profits by catering their political leanings to those of their audience. [21] Entrepreneurs thus have an incentive to produce more subjective content, so long as they are profitable.

Technological innovation has played a major role in upending the traditional media ecosystem. Thirty years ago, newspaper, TV, and radio were the principal forms of news. [22] In turn, networks possessed immense gatekeeping power over what the public knew. [23] Technology has subverted the control of media elites by granting a nearly universal ability to produce information.

Because the media competes in the free market, they have adopted new tactics to attract viewership amidst technological change. The internet and social media have caused an explosion

in the number of media sources, resulting in two momentous business strategy changes. First, instant communication encourages the media to catch the viewer's attention as quickly as possible, prompting extreme methods. [24] For example, these efforts frequently include strong word choice to evoke curiosity from potential consumers. Many of these attempts appear divisive to attract the most attention. Second, news producers feel compelled to distinguish themselves by catering to specific beliefs. [25] The result is niche audiences who enjoy the more consistent partisan coverage. [26] The alterations of the traditional media environment due to technology have increased competition and incentivized more bias.

Another trend stemming from technology is the nationalization of information sources. There is a growing "news desert," where local newspapers are running out of business and ceasing production. [27] People then turn to more national news, focusing on national issues and partisan politics. [28] As a result, discourse becomes more homogenous and consistent with the biases of major national media outlets.

These three components are key contributors to U.S. media bias. Democracy and free market principles respectively provide the legal and economic basis for media to cover news as they choose. New technology allows new forms of media to circumvent the traditional gatekeeping of media giants, meaning that a wider range of ideas can be expressed. Prior to discussing media coverage of 2016 Russian interference, it is first necessary to establish an exact definition of bias within the political media context of this work.

Dr. Adam J. Schiffer, a professor of political science at Texas Christian University, defines partisan bias as when "news content deviates from an ideal, to the benefit of one side of the American political divide." [29] Academics Dr. Timothy Groseclose and Dr. Jeffrey Milyo suggest bias has more to do with "taste" than accuracy, likening bias to "slant." [30] Dr. Tawnya J. Adkins Covert and Dr. Philo C. Wasburn posit that bias is "a consistent tendency to provide more support to one of the contending parties, policies, or points of view in a sustained conflict over a social issue." [31] Common components of bias are favoring one side of an issue and consistency over time.

Schiffer breaks down partisan media bias into four types: gatekeeping, coverage, tone, and quality. Gatekeeping arises when "one side's issue received more coverage than the other side's equally newsworthy issue, or that one side's issue received more/less coverage than it deserved." [32] They frequently encompass scandals, which outlets tend to cover more when their agenda is to paint a picture or policy negatively, and vice versa. Coverage bias is when outlets give "one side of an issue more/less coverage than it deserves." [33] Though similar to gatekeeping, it centers more around the inclusion of one side's talking points over another, rather than simply not covering a topic. Next is tone bias, defined as when "one side is receiving more positive or negative coverage than the other side." [34] A quality charge involves the inclusion of "factual or logical errors that have the effect of favoring one side." [35] Schiffer's categorization of media bias is useful for the purpose of this work, with a particular focus on gatekeeping and tone.

Media Coverage of 2016 Interference

Literature on media bias and coverage of Russian interference during the 2016 election is limited. Justice and Bricker argue that left-leaning media have overapplied the word "hack." [36] They clarify the difference between the Russian Main Intelligence Directorate (GRU) hacking of political organizations and figures and hacking the election, which dangerously overexaggerates Russia's involvement.[37] They contribute a definitional critique of left-leaning media coverage.

A couple of empirical studies of 2016 interference coverage exist. Roeder and Mehta of FiveThirtyEight researched the frequency of CNN, Fox News, and MSNBC mentioning special counsel Robert Mueller's name in 2018. [38] They plotted what percentage of airtime networks devoted to Mueller's investigation and traced reporting with the events of 2018. [39] Roeder and Mehta found that MSNBC devoted the most time to Mueller and Fox News the least amount of time, contributing a general picture of gatekeeping bias among cable news networks. [40]

The most similar research to my own is a Columbia Journalism Review (CJR) study by Howland, Pasquier, and Waniewski. They measured the percentage of prime time – defined as weeknights from 8-11 PM – cable news spent covering the Trump-Russia collusion investigation, as well as subtopics of the investigation. [41] Their research also included a survey to gauge how informed the public is and how much people care about the investigation. [42] The team found a partisan split in weighing the investigation's importance, with left-leaning respondents caring more about the results than those who are right-leaning. [43] Like Roeder and Mehta, they found MSNBC and Fox devoted the most and least airtime to coverage, respectively. [44]

Beyond simply measuring the percentage of prime time discussion of Russian interference, this study seeks to improve on the existing literature through a binary research approach to tone and gatekeeping bias. If Russian interference is discussed in any form, the date will be added to the datasheet. The two aforementioned studies only measure volume as a percentage of airtime, which obscures discerning between shows covering Russian meddling and those which omit discussion. Similarly, for tone bias, when transcripts include any keywords, they count for that date. In other words, there will not be an exact count of how many times words are mentioned. Existing literature only evaluates general topics without explicit reference to tone bias, whereas exact word choice was captured to measure precise talking points, which provides more detailed insight. At this time, there is no specific tone bias research, so this specific contribution to literature will be beneficial. Whereas existing research primarily contributes data, this work ties in elements of the media, bias, Russian interference, national security, and a unique research design to advance the understanding of how cable news exposes viewers to starkly different parts and interpretations of the same news.

METHODOLOGY
Previous Media Bias Studies

Scholars have conducted numerous bias studies varying in approach and methods. Esteemed mass media researcher David D'Alessio measured volume, valence (tone), and topic selection to study media bias of candidates' coverage in presidential elections spanning from 1948 to 2008. [45] Rafail and McCarthy studied the impacts of media bias and portrayals of the Tea Party (a conservative political movement seeking a reduction in the role and size of the United States government) by analyzing the frequency and valence of relevant discussion in newspapers, cable news references, and blog posts by Tea Party groups. [46] They used an automation program to determine positive and negative references to the Tea Party. [47] These studies have a useful methodological approach to evaluating gatekeeping and tone biases in the 2016 election.

Dr. Stuart Soroka conducted a gatekeeping bias study of *The New York Times* on the topic of unemployment from June 1980 to October 2008. He compiled a dataset of articles mentioning employment issues and coded them for tone using *Lexicoder*, an automation software which counts the number of specific words attributed to a predetermined list of positive and negative coverage. [48] The variable tone is calculated as the percent of positive words minus percent of negative, measuring from -10 to +10. [49] Soroka then compared the timeline of actual unemployment statistics to the tone variable and time of *The New York Times*' articles. He applied the same approach of D'Alessio, and Rafail and McCarthy to measure gatekeeping. A similar design, of compiling articles discussing the issue at hand and quantifying keywords to measure the way they portray the issue in comparison to developments over time, is how this research methodology was employed.

CONDUCTED STUDY

The employed methodology most resembles that of Soroka, in measuring gatekeeping and tone bias by capturing the volume and tone of cable news transcripts. The volume portion of this

research evaluates gatekeeping bias by providing an overall picture of how frequently CNN and Fox News discussed Russian meddling, as well as how volume corresponds to real developments. The other component, tone, sheds light on CNN and Fox News narratives and talking points.

Cable news was selected for the subject of the study because of recent changes in cable news reporting style and popularity. Over the last two decades, cable news has become increasingly subjective with a more "argumentative style of news presentation." [50] Bias should thus be evident. Overall, cable news remains widely popular. Between 2017 and 2019, TV as a source for news remained roughly the same, with 58% of respondents citing that they consume TV news at least weekly, lagging only behind online news and social media, with 72%. [51] Though online news is more popular, it is much more decentralized than cable news, as there are scores of sources. Individually, the three major cable news networks – CNN, Fox, and MSNBC –measured just behind local TV as consistent news sources among respondents. [52] Hence, cable news has an enormous audience while providing manageable parameters of study.

CNN and Fox News were chosen because they are the most popular cable news networks. A 2018 survey showed that 19%, 17%, and 27% of respondents from the respective 18-34, 35-54, and 55+ age demographics regularly consume Fox News Channel. [53] This is the highest single rated TV news channel, especially among the 55+ group. Some experts, like Matthew Yglesias, call for further study of Fox News due to its unique relationship with the Republican Party and influence in the realm of political information. [54] 20%, 11%, and 6% of the 18-34, 35-54, and 55+ age groups respectively watch CNN, the most consumed TV news channel with a left-leaning bias. [55] Though also popular, MSNBC was not included in this study for the simplicity of including one left-leaning and one right-leaning network.

In order to conduct an in-depth analysis, the parameters of the study must remain quite narrow. This study examines *Tucker Carlson Tonight* and *Hannity* of Fox News, and *Anderson Cooper 360* and *CNN Tonight* of CNN. [56] The four segments fall into prime time slots, defined as "the time at which the audience peaks" and refers to 8-11 PM on weeknights. [57]

For the gatekeeping bias study, "America's News," a news archive from NewsBank Inc., was used to search for transcripts from each show. Each show was selected and used the advanced search tool to compile all transcripts mentioning Russian meddling. The base search was: "Russia" AND "2016" AND "election" with each a fourth criteria of "meddling," "influence," and "interference" to ensure that all relevant references were included in my data, since Russian efforts encompassed a range of terms. Then, it was verified that all transcripts included relevant discussion, since the 60-minute news segment tended to include a range of topics. Links and dates were collected and inputted into an Excel sheet.

For the tone study, the same base search ("Russia" AND "2016" AND "election") was applied with the rotating fourth search ("meddling," "influence," and "interference") and each keyword [58] as the fifth criteria. Each word was typed into a column corresponding to the relevant row. Table 1 lists the keywords and contextual descriptions they filled to be counted.

Each transcript was verified to ensure that keywords are included only if pertaining to Russian interference. Separate notes of "negative" and "unrelated" mentions were made. Negative mentions are instances where a word or phrase is used but its meaning differs because of context. An example of a negative "hoax" mention would be if the transcript read "Russian influence in the 2016 election is no hoax." Unrelated mentions are those where a word or phrase is used but in a manner in which is different from the criteria captured. For example, "did nothing" refers to President Obama's response to Russian meddling efforts, but an unrelated mention would capture an instance where a transcript says the intelligence community "did nothing." Because a key phrase could be considered both "regular" and "unrelated" if used more than once, the "regular" mention takes precedence. It should be assumed that data is considered a normal mention if not otherwise specified.

The time frame of this study is from May 1, 2016 to April 30, 2019. The three-year period includes the majority of Russian efforts to

Table 1. Keywords and Contextual Descriptions

Word/Phrase	Definition and Context
Bombshell	Descriptor of a major event, can be used by either network.
Conspiracy[59]	Used in the same manner "conspiracy theory."
Delegitimize	Decertifies President Trump or his election because of Russian interference.
Did nothing	Conveys the argument that President Obama did not respond correctly to intelligence about Russian meddling efforts.
Discord	Pertains to Russia's goal to fuel division in American society, frequently mentioned in in official U.S. Government reports.
Downplay	Refers to efforts of President Trump and his associates to diminish the threat of Russian electoral interference.
Fake news	Descriptor of questionable reporting.
Fair and square	A point of emphasis that the election results were legitimate, regardless of Russian efforts to affect the election.
Help Trump	Stresses that President Trump benefited from Russian meddling.
Hoax	Characterization of official investigations about Russian interference and possible collusion between Trump and/or associates and Russia.
Hysteria	Exaggeration of claims about the results of Russian election interference and/or potential collusion.
No collusion	A point of emphasis that there was no collusion between any Trump associates and Russian agents to support Trump's campaign.
No evidence	Two contexts – (1) lack of proof that Russia altered the election outcome, and (2) the principal finding of Mueller's Russia investigation, officially because there was not sufficient evidence to convict Trump of colluding with Russia.
Obstruct	Pertains to President Trump's alleged efforts to tamper with evidence in the investigation of possible collusion.
Puppet	References the view that Trump being a puppet to Russian President Vladimir Putin.
Putin	Mentions of the Russian President.
Smoking gun	A damning piece of evidence.
Undermine	Regards Russian influence weakening American democracy.
Witch hunt	Characterizes that political motivations are the motives for investigating Trump.

interfere in the 2016 election, in addition to most of the investigations. March, April, and May of 2016 are when Russian hackers stole emails and data from the Democratic National Committee, Hillary Clinton's Campaign Chair John Podesta, Democratic Congressional Campaign Committee, and Clinton staffers. The Mueller Report was released in April 2019, serving as a concluding milestone for 2016 interference discourse.

RESULTS

Overview

Table 2 provides a snapshot of data by show. The "relevant shows" column refers to the number of transcripts discussing Russian interference or subsequent investigations. *CNN Tonight* and *Cooper* spoke about the topic on a nearly equal number of shows, with 277 and 279, respectively. Fox, on the other hand, varied much more, with 228 discussions on Hannity and 146 on Carlson. The same discrepancy is true for keywords, with CNN shows differing only by 53 keywords and Fox programs by a staggering 638.

Table 2. Average Keywords Mentioned Per Relevant Show

Show Title	Relevant Shows	Keyword Mentions	Keywords per Show
Carlson	146	375	2.57
Hannity	228	1013	4.44
CNN Tonight	277	706	2.55
Cooper	279	653	2.34
Total	930	2747	2.98

It is unequivocal that CNN covers Russian electoral interference more frequently than Fox. 745 non-public holiday weekdays fell into the study's time frame, giving a rough estimate of the total number of airings for each show. A quick calculation shows that CNN Tonight and Cooper discussed Russian interference on about 37% of their shows from May 2016 to April 2019. Fox was more split, as Hannity did so on approximately 31% of shows and Carlson at 24%. [60]

A wide range exists in the number of keywords mentioned in each transcript. Table 3 displays aggregate data where the total number of shows are broken down according to ranges of the key phrases mentioned. The first row of Table 3 shows that one hundred segments stated no keywords, though they talked about Russian interference. The majority of transcripts, at 66.99%, contain 1-4 keywords, suggesting a moderate level of consistent references to keywords.

Table 3. Total Keyword Ranges by Relevant Show

Words	Total Number of Shows	Percentage (%)
0 words	100	10.75
1-4 words	623	66.99
5-8 words	197	21.18
9+ words	10	1.08
Total	930	100.00

Next, several hypotheses about the data were tested.

Hypothesis 1 (H1): Shows from the same network mentioned keywords at similar rates.

Table 4 displays the percentage of individual shows referencing keywords. *CNN Tonight* and *Cooper* mentioned key phrases at similar rates, even for words stated more than one hundred times, such as "Putin" and "fake news." Table 3 reveals that the two discussed Russian interference on an almost identical number of shows, meaning they said phrases almost the same number of times. The largest discrepancy is "no evidence," which only varied by roughly ten percent. *Hannity* and *Carlson* are quite different. Only with seldomly used words like "discord" and "undermine" were there comparable usage rates with an adequate sample size of over 40.

Table 4. Percentage of Each Total Show Mentioning Keywords

Word/Phrase	Carlson (%)	Hannity (%)	CNN Tonight (%)	Cooper (%)	Total Keyword Mentions
Hoax	15.07	41.67	13.36	12.19	188
Fake News	26.71	68.86	23.10	21.86	321
Witch Hunt	16.44	57.02	31.05	25.81	312
Hysteria	22.60	30.70	1.08	1.43	110
Conspiracy	23.29	47.37	6.86	3.58	171
Did Nothing	2.74	11.40	0.72	2.15	38
No Collusion	13.01	35.53	33.57	25.09	263
No Evidence	48.63	60.09	17.69	27.24	333
Delegitimize	4.79	17.54	1.81	3.94	63
Fair and Square	2.05	3.95	1.08	1.79	20
Bombshell	4.11	16.67	15.16	10.75	116
Smoking Gun	0.00	7.89	3.25	3.58	37
Downplay	0.00	0.00	1.81	2.15	11
Obstruct	10.96	15.79	21.66	24.37	180
Puppet	4.11	0.88	3.97	1.08	22
Putin	50.68	16.67	51.62	48.39	390
Help Trump	2.05	0.44	6.86	3.58	33
Discord	1.37	3.95	7.58	5.02	46
Undermine	8.22	7.89	12.64	10.04	93

Tables 5a-d present the key phrases used in more than 20 percent of an individual show's transcripts. Common between Carlson and Hannity are "no evidence," "fake news," "conspiracy," and "hysteria," though the margins vary immensely, as is evident in Tables 5a and 5b. Out of his own top six most stated keywords, Hannity used all five buzzwords, a category of popular words frequently used by President Trump including "hoax," "hysteria," "fake news," "witch hunt," and "conspiracy." An astoundingly high percentage of Hannity's transcripts included these words, suggesting a repetitive presentation style with shallow analysis.

Tables 5c and 5d show similar discussion between Cooper and CNN Tonight. The two used "Putin," no collusion," "fake news," and "obstruct" at similar rates and were approximal with "witch hunt." The only discrepancy was "fake news," voiced more by CNN Tonight, and "no evidence," by Cooper.

Table 5a. *Carlson* Keyword Highlights

Word/Phrase	Count	% of Shows
Putin	74	50.68
No Evidence	71	48.63
Fake News	39	26.71
Conspiracy	34	23.29
Hysteria	33	22.60

Table 5b. *Hannity* Keyword Highlights

Word/Phrase	Count	% of Shows
Fake News	157	68.86
No Evidence	137	60.09
Witch Hunt	130	57.02
Conspiracy	108	47.37
Hoax	95	41.67
No Collusion	81	35.53
Hysteria	70	30.70

Table 5c. *CNN Tonight* Keyword Highlights

Word/Phrase	Count	% of Shows
Putin	143	51.62
No Collusion	93	33.57
Witch Hunt	86	31.05
Fake News	64	23.10
Obstruct	60	21.66

Table 5d. *Cooper* Keyword Highlights

Word/Phrase	Count	% of Shows
Putin	135	48.39
No Evidence	76	27.24
Witch Hunt	72	25.81
No Collusion	70	25.09
Obstruct	68	24.37
Fake News	61	21.86

In an effort to control the study, cable news data was compared to that of the Associated Press News Wire for one randomly selected month. News wires typically come in multiple times a day, so the volume is different by nature from cable news, which occurs once a day at most. As a result, there is no volume comparison in the control. To compare keywords, the raw data was converted to percentages of news wires including keywords.

In March 2018, there were 75 news wires about Russian interference with 77 keywords, and 48 relevant cable news transcripts with 156 key phrases. Raw numbers were converted to percentages to show the rate at which each mentioned keywords, as depicted in Table 6. For example, 41.67% of Hannity transcripts from March 2018 include "no collusion."

Table 6. Percentage of Program's Total March 2018 Sources Mentioning Keywords

Words	Carlson (%)	Hannity (%)	CNN Tonight (%)	Cooper (%)	AP (%)
Hoax	25.00	16.67	0.00	0.00	0.00
Fake News	50.00	75.00	29.41	33.33	1.33
Witch Hunt	0.00	58.33	29.41	13.33	8.00
Hysteria	50.00	25.00	0.00	0.00	0.00
Conspiracy	25.00	66.67	5.88	6.67	0.00
Did Nothing	0.00	41.67	0.00	0.00	2.67
No Collusion	25.00	41.67	29.41	40.00	16.00
No Evidence	75.00	83.33	17.65	20.00	17.33
Delegitimize	0.00	33.33	0.00	6.67	0.00
Fair and Square	0.00	0.00	0.00	0.00	0.00
Bombshell	0.00	16.67	11.76	13.33	0.00
Smoking Gun	0.00	0.00	0.00	6.67	0.00
Downplay	0.00	0.00	0.00	0.00	1.33
Obstruct	0.00	0.00	5.88	26.67	16.00
Puppet	0.00	0.00	11.76	0.00	0.00
Putin	50.00	41.67	70.59	66.67	24.00
Help Trump	0.00	0.00	11.76	6.67	4.00
Discord	0.00	16.67	5.88	13.33	5.33
Undermine	25.00	8.33	11.76	6.67	6.67
Total Transcripts	4	12	17	15	75

Representing a more objective lens, the AP News Wire demonstrates that Fox and CNN use keywords at much higher rates. The only approximate rates to AP are Cooper's use of "witch hunt," CNN Tonight and Cooper mentions of "no evidence," CNN Tonight and "discord," and Cooper and Hannity's incorporation of "undermine." Rates may change if the control were expanded to six months, but the AP data suggests that cable news on both sides of the political spectrum sensationalized Russian interference.

Figure 7 exhibits the keyword count ranges from Table 3 broken down by show. It visualizes how great of an outlier *Hannity* is, where nearly half of relevant transcripts used five to eight keywords. Referencing Table 5b, it is inferable that a majority of these shows included one or more buzzwords.
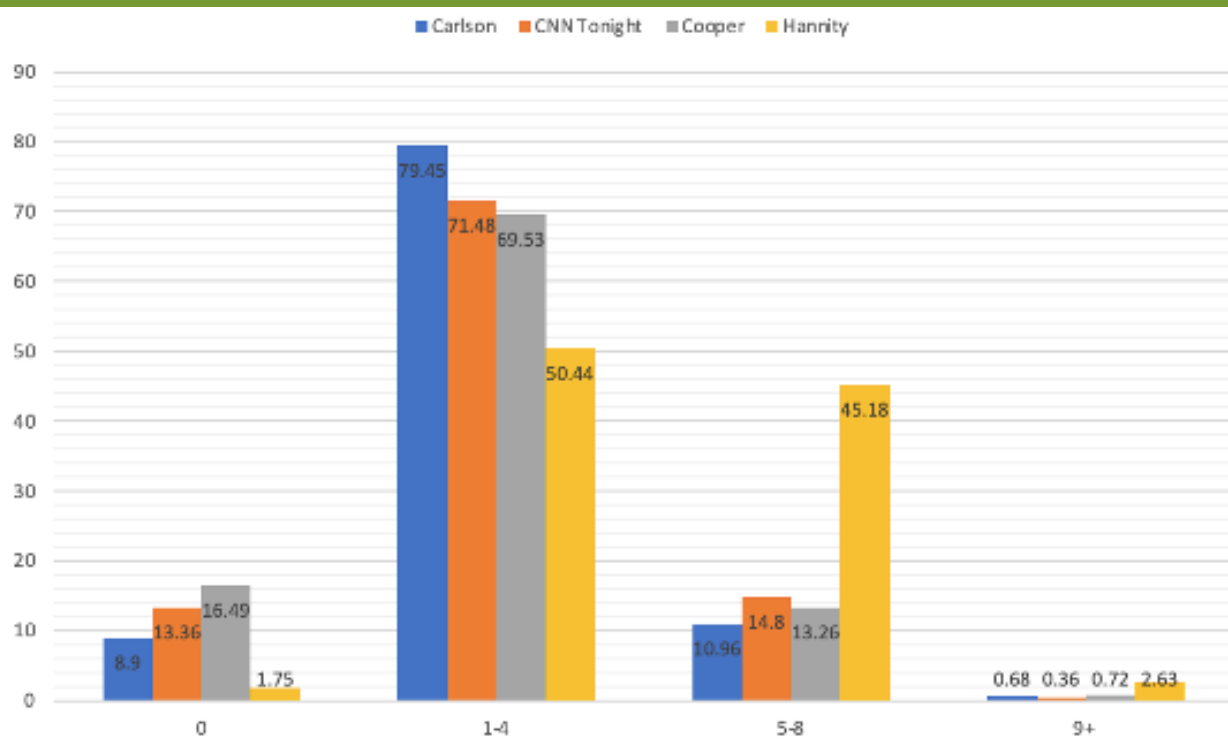

Figure 7. Keyword Count Ranges by Program

While Tables 4 and 5 suggest that CNN shows had similar talking points, the same conclusion cannot be made for Fox News. Thus, we must reject Hypothesis 1. In further testing, it is necessary to distinguish between programs.

Hypothesis 2 (H2): Fox News and CNN had different talking points. Fox emphasized that Russia did not impact the election's outcome and that investigations were politically-motivated, while CNN focused on national security and allegations of collusion between Russia and the Trump campaign. [61]

To measure this, phrases representing these expected viewpoints were analyzed. "No evidence," "no collusion," and "delegitimize" represent the politically-right views of election legitimacy and political intention. "Discord," "undermine," "help Trump," and "obstruct" encompass the politically-left points of national security and allegations of Trump-Russia collusion.

Table 8 displays how Hannity overwhelmingly used the first

three words, representing the more right-leaning points of emphasis. Even when viewed as rates, in Table 9, Hannity referenced these talking points much more frequently than all other shows. Hannity accounted for nearly two-thirds of all "delegitimize" mentions, and continually emphasized the notion that Russia probes were an attack on Trump.

Tables 8 and 9 show that Fox News declared "no evidence" at higher rates than CNN. However, CNN stated "no evidence" in one hundred unrelated contexts, many in relation to Trump's claims that the Obama administration wiretapped Trump Tower, to Fox's three. That CNN said "no collusion" more often than Fox contradicts expectations based on political leanings and the context of keywords. Referencing Table 1, we recall that "no evidence" has two meanings – Russian actions not directly impacting votes, and the lack of evidence to find the Trump campaign guilty of colluding with Russia. In both contexts, "no evidence" stressed the view that the election was not rendered illegitimate. It also supported the right-leaning view that the Mueller probe was unwarranted. On the other hand, "no collusion" focused more on Mueller's official findings. CNN's higher rate of "no collusion" may be attributable to its presentation style, which often included playing video clips of and reading tweets by Trump. [62] The subtle distinction provides a clearer understanding of the differences between CNN and Fox agenda items.

Table 8. Talking Point Word Counts by Show

Word/Phrase	Carlson	Hannity	CNN Tonight	Cooper	Total
No Collusion	19	81	93	70	263
No Evidence	71	137	49	76	333
Delegitimize	7	40	5	11	63
Total	**97**	**258**	**147**	**157**	**659**
Help Trump	3	1	19	10	33
Discord	2	9	21	14	46
Undermine	12	18	35	28	93
Obstruct	16	36	60	68	180
Total	**17**	**28**	**75**	**52**	**172**

CNN mentioned the four bottom words much more frequently than Fox. It appears in Table 8 that Fox was hesitant to state "help Trump," suggesting that it was unwilling to concur with official intelligence assessments that Trump benefited from Russian actions. "Discord," included in official government assessments as a goal of Russia, referred more to influence efforts, about which CNN reported more than Fox. [63] CNN and Fox used "undermine" at low but comparable rates, though much of the raw numbers are much higher by CNN, which suggests that it discussed Russian intentions more often. It is unsurprising that CNN used "obstruct" at higher percentages than Fox, because critics have touted the left-leaning media for overexaggerating claims that Trump colluded with Russia and then obstructed Mueller's investigation. [64]

Table 9. Talking Point Percentages of Each Total Show

Word/Phrase	Carlson (%)	Hannity (%)	CNN Tonight (%)	Cooper (%)
No Collusion	13.01	35.53	33.57	25.09
No Evidence	48.63	60.09	17.69	28.15
Delegitimize	4.79	17.54	1.81	3.94
Help Trump	2.05	0.44	6.86	3.58
Discord	1.37	3.95	7.58	5.02
Undermine	8.22	7.89	12.64	10.04
Obstruct	10.96	15.79	21.66	24.37

Tables 8 and 9 exemplify how Fox News and CNN tended to stress different components of Russian interference. Apart from "no collusion," the data supports H2 because Fox discussed more about the political intentions of investigations and lack of impact by Russian actions, whereas CNN focused on national security risks and obstruction allegations. Examining politically-charged keywords supports H2.

Hypothesis 3 (H3): Fox News stated buzzwords at higher rates than CNN.

President Trump's tweets and public speaking about Russian interference regularly included buzzwords like "hoax," "fake news," "witch hunt," "hysteria," and "conspiracy." These five words are the subject for H3.

Table 10 displays the raw numbers of buzzwords by each show. Fox News used nearly two-thirds of buzzwords, though Hannity alone

accounted for almost 80 percent of Fox's use. Hannity's overwhelming reference of buzzwords was evident. In fact, buzz words comprised over half of Hannity's total keyword (1,013) references.

Table 10. Buzzword Counts by Show

| Word/Phrase	Carlson	Hannity	CNN Tonight	Cooper	Total
Hoax	22	95	37	34	188
Fake News	39	157	64	61	321
Witch Hunt	24	130	86	72	312
Hysteria	33	70	3	4	110
Conspiracy	34	108	19	10	171
Total	152	560	209	181	1102

Carlson used buzzwords more modestly in volume, but at high rates nonetheless. Of his 375 total keyword references, buzzwords accounted for approximately 40 percent. Unlike his prime time compatriot, he tended to stay away from "hoax" and "witch hunt," which both *Cooper* and *CNN Tonight* repeated at higher rates. "Hysteria" stood out as a word used uniquely by Fox News, consistent with the view that the Russia investigations were part of unreal hysteria about Russian electoral meddling.

Table 11. Buzzwords Percentage by Each Total Show

Word/Phrase	Carlson (%)	Hannity (%)	CNN Tonight (%)	Cooper (%)
Hoax	15.07	41.67	13.36	12.19
Fake News	26.71	68.86	23.10	21.86
Witch Hunt	16.44	57.02	31.05	25.81
Hysteria	22.60	30.70	1.08	1.43
Conspiracy	23.29	47.37	6.86	3.58

Tables 10 and 11 support H3 by displaying that *Hannity* and *Carlson* referred to buzzwords by percentage of shows than *CNN Tonight* and *Cooper*.

Hypothesis 4 (H4): Either one or both of CNN and Fox demonstrated gatekeeping bias by discussing Russian interference at times favorable to current events. Fox News increased volume following an occurrence supporting the view that Russia did not impact the election and/or that there was no collusion between the Trump campaign and Russia. CNN's volume increased after events which strengthened the argument that Trump colluded with Russia and emphasized national security concerns.

Figure 12 tracks the total discussion by each show over the three-year period. The first information spike occurred in January 2017, around Trump's inauguration and when more information came to light about Russian interference. CNN and Fox News jumped again in March 2017, though CNN doubled Fox discussion. Cooper's volume reached its maximum in June 2017, shortly after the Mueller investigation began. CNN Tonight stood out for frequent discussion in March 2018 and January 2019, while Hannity increased sharply in March and April 2019, presumably about the Mueller report release.
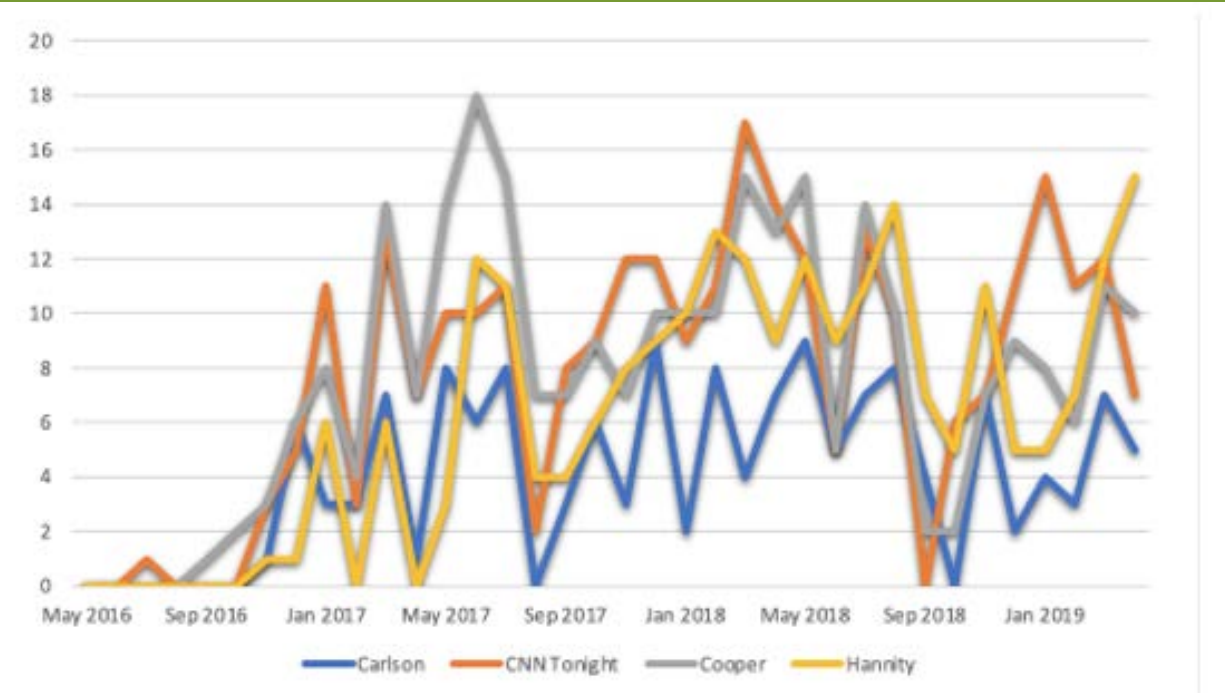
Figure 12. Total Discussion of Russian Interference

To thoroughly evaluate gatekeeping bias, five events were analyzed as case studies. For a breadth of events, three are politically neutral because they center around government actions, while one event each more clearly favors the views of the left, focusing on national security concerns, and right, emphasizing the issue's political motives. The day of the event, plus the next four are examined closely. [65] Therefore, a maximum of ten shows from each network can be listed as

having relevant discussion. To determine gatekeeping bias, three ranges are applied. Zero to three shows denote "low" gatekeeping bias on the part of a network to avoid discussion about the event which just occurred. Four to six shows signify an average amount of conversation and serve as a rough baseline. A case with seven to ten subsequent shows demonstrates "high" gatekeeping bias" by hosting frequent discussion.

The first case is on the ODNI's "Assessing Russian Activities and Intentions in Recent US Elections" assessment from January 6, 2017. The report declared that the Russian government attempted to undermine faith in the election process, harm Secretary Clinton's electability, and help Trump win the election, while concluding that efforts did not alter vote tallies. [66] Because the report does not favor a particular political agenda, coverage would be expected to be similar for Fox and CNN. All four shows discussed interference on January 6, though dialogue dropped by Fox News shortly thereafter. In total, three Fox and eight CNN shows out of a possible ten each discussed interference after the ODNI report, demonstrating low and high levels of gatekeeping, respectively. Seven of the eleven total programs mentioned "Putin" which likely refers to the report's assessment that Putin ordered the interference efforts. "Undermine," another word used in the report in reference to Russia's intention to harm U.S. democracy, was mentioned six times. Thus, there is evidence of gatekeeping bias from CNN, for emphasizing the report more, and Fox, for speaking of it less.

The Nunes memo, released on Friday, February 2, 2018, detailed alleged Federal Intelligence Surveillance Act (FISA) violations by the FBI and Justice Department to track Carter Page, a former Trump campaign staffer. [67] The House Intelligence Committee, with a Republican majority, supported the notion that surveillance was politically charged. [68] As such, it would be expected for Fox News to capitalize on the news and have more relevant shows than CNN in the following days. Fox shows discussed interference six times in total, while CNN only did so four times. Both networks fell into the average gatekeeping level, but at opposite ends, as expected with the Nunes memo's political implications. "Fake news" was a popular word, used six total times, five of which came from Hannity, suggesting repetitive word choice. There is inconclusive evidence to conclude that gatekeeping bias was present by either CNN or Fox.

On February 16, 2018, special counsel Mueller indicted three Russian organizations, including the Internet Research Agency (IRA), and thirteen Russian citizens for attempting to influence the American electorate. The IRA created fake personas on social media to create content provoking real Americans on divisive issues, reaching millions of Americans. [69] As a politically neutral event, we would expect relatively even coverage from both networks. In total, CNN discussed the issue on nine out of a possible ten relevant shows, as compared with seven from Fox, both falling into the high gatekeeping level. Comparing keywords from these 16 programs illuminates how both networks used the event for their political slants. Recall the conclusion of H2 which suggested that Fox emphasized the unknown impact of the IRA, while CNN focused on discord sowed by the IRA and its damage to U.S. democracy. Popular keywords were "fake news" with 11 references, presumably because the IRA spread disinformation, and "Putin," though neither were stated in the indictment. [70] All seven Fox News transcripts included "no evidence," while CNN only said the phrase twice. There were five mentions of "discord" and "undermine," but the latter was not included in the indictment, suggesting that news networks discussed how the IRA's efforts intended to subvert American democracy. Post-indictment volume was high for both CNN and Fox, though it is important to note the difference in rhetoric.

On January 25, 2019, the FBI arrested Roger Stone, a close friend and adviser to President Trump on charges of lying to Congress, witness tampering, and obstruction. [71] The charges against Stone centered around hiding communications with WikiLeaks to acquire damaging information about Secretary Clinton and planning a strategic release of emails hacked by the Russian GRU. [72] Stone's arrest fueled Trump-Russia collusion allegations, so it is expected that CNN would have higher volume than Fox in the following days. CNN and Fox discussed interference six times and twice, respectively, demonstrating low gatekeeping bias on the part of Fox for avoiding

On April 18, 2019, the Department of Justice released a redacted version of the Mueller report. It stated "the evidence was not sufficient to support criminal charges" of collusion between Trump campaign officials and Russian government representatives. [73] The Mueller report was a momentous development, thus high, but comparable, coverage would be expected. Fox accounted for six relevant shows, while CNN did so seven times. Though Fox coverage fell into the baseline gatekeeping category and CNN into high gatekeeping, they are relatively equal. "No collusion," "fake news," and "witch hunt" were popular terms in the Mueller report's wake. Eight transcripts included "hoax," of which six were Fox, suggesting that Hannity and Carlson stressed that the investigation was inappropriate and politically motivated. Again, CNN and Fox raised different points, though their output was proximate, so gatekeeping bias is inconclusive in this case.

These five case studies illuminate some evidence of gatekeeping bias. CNN had higher levels of gatekeeping, stressing the national security implications and discussion about possible Trump-Russia collusion. Fox had a wider array but lower volume of coverage, tending to eschew negative events and focus more on events supporting its political bias. Discrepancies in reporting volume after the January 2017 intelligence assessment and Roger Stone arrest suggest that CNN supported its view of interference with these events more than Fox. Comparable coverage volume following the IRA indictment and Mueller report supports the notion that each network put its own spin on the events to interpret the report in their political favor.

BOMBSHELL

Analyzing one key word, "bombshell," provides a particularly interesting perspective. Fox and CNN used it to describe starkly different events. In the context of H4, we would expect CNN and Fox to have mentioned these words at different times, represented by asynchronous spikes. Figure 13 illustrates some asynchronous reporting, though it also consists of concurrent increases. Further contextual analysis of the May 2017 CNN spike showed some discussion of memos from FBI Director James Comey to President Trump, including Trump's request that Comey end the investigation of National Security Adviser Michael Flynn, and the initial report about Jared Kushner's meeting with the Russian Ambassador. July 2017 saw an increase by all shows, however, CNN and Fox discussed very different issues. CNN stressed meetings between Trump officials and Russian lawyers and the Trump administration undermining Mueller's investigation. Fox, namely *Hannity*, attacked the Obama administration with accusations of NSA civil liberties violations, the Department of Justice allowing a Russian lawyer into the country, and a DNC operative trying to sabotage Trump with Ukraine. Therefore, the July 2017 spike in mentions of "bombshell" illustrated both networks applying the word to its talking points.
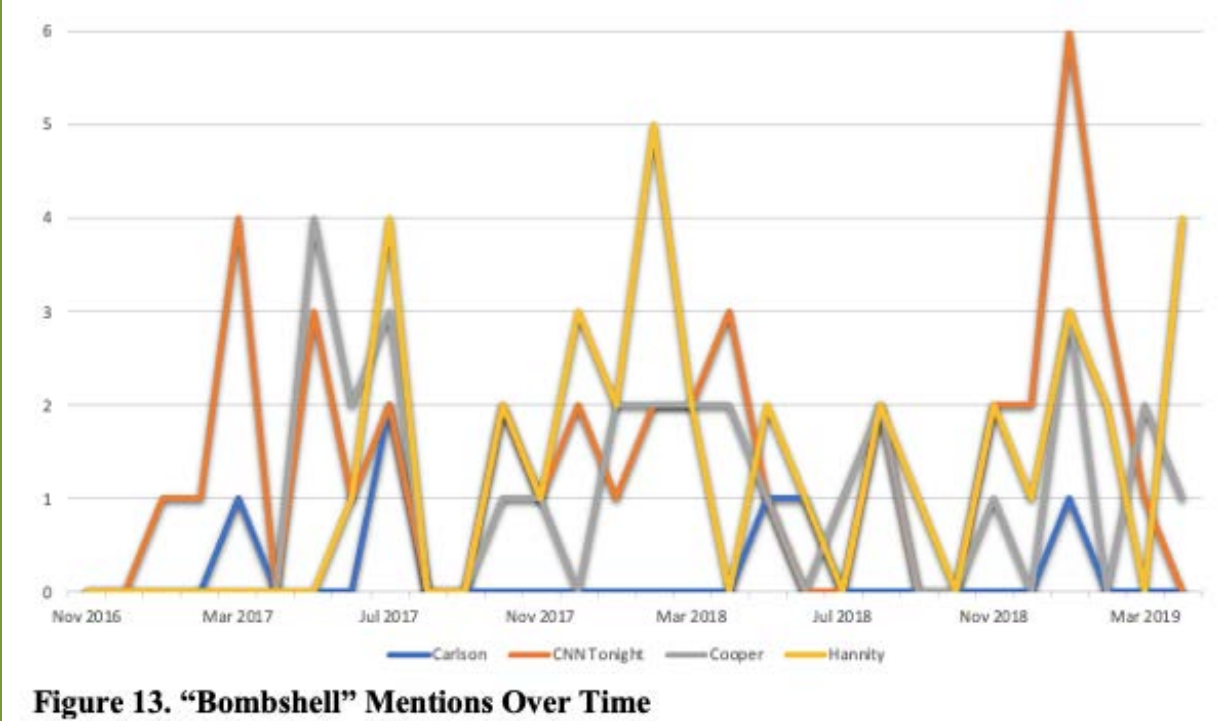
Figure 13. "Bombshell" Mentions Over Time

Both CNN shows and Hannity experienced an increase in February 2018. Hannity repeated information about the Obama administration abusing FISA and politicizing the Steele dossier. CNN mentioned FISA once – though it sowed doubt on the claim because it came from Trump supporters – reading tweets from

President Trump, and Mueller's indictments of thirteen Russian citizens. A universal spike occurred in January 2019, though again with different spins. Fox emphasized the impactful contents of WikiLeaks-released emails, while CNN focused on reports about Trump's counterintelligence risk after firing Comey, Russian-Trump official collaboration evidence, and the links between Roger Stone and Trump. *Hannity* spiked once more in April 2019. Discussion centered around a FISA abuse investigation and Mueller report contents. Though the use of "bombshell" by CNN and Fox News sometimes rose at similar times, they were applied in dissimilar contexts which supports the use of spin for each network.

Overall coverage, shown in the "relevant shows" column of Table 2 and Figure 12, displays a tendency by CNN to cover Russian interference more frequently. The case studies illustrate a propensity for CNN to have augmented interference discussion more following developments neutral or favorable to its political slant, and aversion for Fox to have covered unfavorable events. The "bombshell" analysis shows how CNN and Fox employed the keyword to describe events favorable to their own talking points.

DISCUSSION & CONCLUSION

H1-3 evaluated tone bias for Fox and CNN. H1 illuminated how *Hannity* and *Carlson* varied in the use of keywords, disallowing generalizations about Fox and requiring a closer examination for further hypotheses. When compared to the control, it also demonstrated that both CNN and Fox sensationalized Russian interference. H2 showed how both cable networks put their own spin on developments to fit their political slant. Tables 7 and 8 illustrated Fox's stronger weight on the phrases "no evidence" and "delegitimize," suggesting more emphasis on insufficient evidence and partisan bias by investigators. Consistent with national security concerns and Trump collusion allegations, CNN used "discord," "undermine," "help Trump," and "obstruct" at higher rates. H2 supported the idea that Fox and CNN applied language favorable to their political views. Tables 9 and 10 confirmed H3's assertion that Fox mentioned buzzwords at higher volume and rates than CNN, suggesting a more sensationalized, repetitive, and subjective reporting style. Fox's audience was more likely to be exposed to pathetical, less factual claims.

H4 examined gatekeeping bias through five cases and use of "bombshell." The case studies demonstrated some tendency for Fox to decrease relevant volume following a development more contradictory to its political views, namely the low volume after the January 2017 assessment and Roger Stone arrest. CNN favored more frequent coverage overall but did come close to a low level of gatekeeping after the Nunes memo release. Similar volume following more politically neutral developments, plus the "bombshell" study, illustrates how both networks spun events to their political favorability.

While my study is in-depth, there are some limitations. It included only two cable news networks, of which only two shows from each network are studied. *Hannity*, *Carlson*, and *Cooper* fit more closely into the genre of political commentary, meaning that each host has more autonomy in deciding what to discuss on their show. *CNN Tonight* resembles a more traditional news desk, giving briefs of current events, so discussion tends to be shorter and more objective. The networks may also vary in the number of video clips they play or guests of political views differing from their bias, which could have impacted keyword counts.

The conflicting talking points presented by CNN and Fox about Russian election interference are a gravely concerning trend, especially as their ratings prove they are major sources of information for millions. However, *Hannity*, *Carlson*, *Cooper*, and *CNN Tonight* only represent a sliver of the political news landscape. A holistic view of the American media, as affected by the freedom of the press, business principles altering news production, and technological advancements subverting traditional gatekeeping, may demonstrate greater divide among other news sources, like radio, social media, and website news. Further study on other media platforms would be an intriguing comparison and provide depth to bias coverage studies on Russian meddling in 2016.

This study only evaluates the messages of CNN and Fox. Additional study is needed to assess how information impacts the beliefs and actions of its consumers. A potential study of interest could be polarization. Tone and gatekeeping bias are pertinent issues, especially when considering how the starkly different messages of CNN and Fox may impact the beliefs and actions of its viewers. Martin and Yurukoglu posit that viewers who consume news from sources catering to their preexisting political preferences can spark a feedback loop where news moves one's beliefs further away from center, which causes the consumption of decreasingly centrist news. [74] Applying the polarization feedback loop theory would be a beneficial application of my data.

Recently, millions of Americans turned on cable news channels for Election Night 2020 coverage. Showcasing the influence of cable news, analysts and experts employed by cable outlets are generally the ones who report on voter counts, up-to-the-minute developments, and declare winners. On this past election night, there was a hesitancy to declare a winner for days due to extraordinarily competitive swing states and counting of mail ballots. However, on Saturday, November 7, 2020 – four days later – CNN called the election in favor of Biden, soon followed by other networks, sparking a wave of celebrations among Biden supporters across the country. [75] Though still not accepted by some, as legal proceedings over mail-in ballots remain pending as of this work's writing, the agreement of cable networks signaled the election results to the majority of Americans. However rare, concurrence among the networks also communicated the election's legitimacy to its millions of viewers. These indicators exhibit the immense power held by cable news outlets.

This study's inward look at the nation's major political information sources media bias has perhaps never been more important. The current decentralized state of the media, where gatekeeping by media elites is subverted by evolving technology, makes the U.S. vulnerable to foreign information manipulation in elections and routine life. As we progress further into the age of information, it will become ever more vital to beware of information sources and bias.

Footnotes

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[56] Condensed names may be used for show titles. Tucker Carlson Tonight may be shortened to Carlson and Anderson Cooper 360 may be shortened to Cooper.
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[58] Note that I will refer to "keywords" as "key phrases" interchangeably for simplicity.
[59] Conspiracy was sometimes used in a legal context as an accusation against Trump's campaign to collude with Russian contacts, but I documented these as unrelated mentions.
[60] Carlson did not begin airing until November 14, 2016 so its calculation was 146 (the total relevant shows) divided by 609 (non-public holiday weekdays).
[61] Laura Galante and Shaun Ee, "Defining Russian Election Interference," Atlantic Council, Issue Brief, September 2018, 11. https://www.atlanticcouncil.org/wp-content/uploads/2018/09/Defining_Russian_Election_Interference_web.pdf.
[62] This is from my own observations when verifying relevant shows and keyword mentions.
[63] ODNI, Assessing Russian Interference, 2017.
[64] Mark Serrano, "Four Lamest Excuses for the Media's Russia Coverage," Real Clear Politics, March 29, 2019, https://www.realclearpolitics.com/articles/2019/03/29/four_lamest_excuses_for_the_medias_russia_coverage_139893.html.
[65] Because these prime time shows only take place on weeknights, an event taking place on a Friday will garner analysis for that Friday and the following Monday through Thursday.
[66] ODNI, Assessing Russian Activities and Intentions, ii.
[67] Chad Day, "What the GOP Memo Says (And Doesn't Say)," AP News, February 2, 2018, https://apnews.com/article/a24b89a2d5ca421da76ce3a1d9775ed3.
[68] Day, "What the GOP Memo Says," 2018.
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[70] United States of America v. Internet Research Agency LLC et. al., (D.D.C 2018).
[71] Eric Tucker and Chad Day, "Trump Confidant Stone Charged with Lying about Hacked Emails," AP News, January 25, 2019, https://apnews.com/article/1dcac576e9964f3d98b96b8052f61f8c.
[72] Tucker and Day, "Trump Confidant Stone Charged," 2019.
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[74] Gregory J. Martin and Ali Yurukoglu, "Bias in Cable News: Persuasion and Polarization," American Economic Review 107, no. 9 (2017): 2568. https://doi.org/10.1257/aer.20160812.
[75] John Koblin, Michael M. Grynbaum, and Tiffany Hsu, "Tension, Then Some Tears, as TV News Narrates a Moment for History," The New York Times, November 7, 2020, https://www.nytimes.com/2020/11/07/business/media/presidential-election-tv-networks-call.html.

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About the Author

Collins K. Alexander is a senior at UNC. Growing up in the information age, with widespread accessibility and almost instantaneously spread, made him interested in how people use information. Through readings and research papers as a Peace, War & Defense and Global Studies major, he became fascinated with disinformation. With a national security lens, he has grown weary of how nefarious actors can intentionally plant falsified information for gain. Collins further explored the issue through a research position with the Foreign Policy Research Institute's "Foreign Influence Election 2020" project, where the analyzed and coded articles from Russian, Iranian, and Chinese state-sponsored media outlets, and wrote blog posts. Wanting to dive deeper into how foreign adversaries can influence the beliefs of Americans, plus a desire to evaluate slanted messages from news outlets on an enormous issue during a momentous election in American history, he decided to write an honors thesis. Collins conducted a self-designed research project to examine how American cable news portrayed Russian meddling efforts in the election. Maintaining the lens of national security, the reach of cable news to millions of Americans each night is alarming because of politically charged reporting styles and language, impacting the beliefs of viewers. America is severely divided and a deep examination of the political information sphere is necessary to combatting internal division.

An Integrative Approach to Biculturalism: Analysis of Acculturative Strategies' Effects on Asian Adolescents' Psychosocial Well-Being and Ethnic Identity Development

by Lang Duong

The formation of ethnic identity during critical developmental periods (i.e., adolescence) is a vital process in establishing an individual's self-concept. Due to increased Asian immigration rates and their unique title as a "model minority," Asian Americans are a specific population of interest when studying the effect of acculturation strategies on psychosocial well-being and ethnic identity development as they integrate into Western society. This report gathered findings across six different research studies with a sample composed mainly of Asian high school and college students. Consistent with previous research, marginalized acculturative strategy users suffered the worst psychological adaptive outcomes, reported the lowest overall quality of life, and expressed the lowest ethnic identification with both the heritage and dominant culture. Separated acculturative strategy users experienced feelings of confusion when attempting integration into the dominant culture and reported higher levels of acculturative stress, thus leading them to stay connected mainly to their heritage culture. Assimilated acculturative strategy users are also at risk for negative developmental outcomes; however, this risk increases as these users' self-concept becomes increasingly dependent on their acceptance into the dominant culture. Finally, achieving bicultural competence through the use of an integrated acculturative strategy leads to the most positive psychosocial outcomes including resilience, higher self-esteem, social connectedness, etc. While the findings from this report are a formative step to understanding the Asian American experience, the gap between research and policy changes needs to be bridged.

Keywords: Asian adolescents, ethnic identity, development, immigrant, acculturation

Analysis of Acculturative Strategies' Effects on Asian Adolescents' Psychosocial Well-Being and Ethnic Identity Development

Adolescence is arguably a critical period for identity exploration and has been a focal interest of various research topics. Researchers have sought to understand how adolescents define their sexual and gender identities, develop their personalities, and identify with specific peer groups, as well as the underlying mechanisms accelerating these processes. However, one of the most understudied and overlooked aspects of identity exploration is the development of ethnic identity in youth. Many studies are severely populated with participants from Western, educated, industrialized, rich, and democratic (WEIRD) societies, leading to an unrepresentative sample of the United States' diverse population and less desire to study how ethnic identity is formed in minority youth. This report seeks to address these disparities in research, understand the presentation of ethnic identity throughout adolescence in Asian teens, and learn how differing identity formation techniques can impact psychosocial well-being.

LITERATURE REVIEW

Ethnic Identity Development

As previously stated, an important facet to one's identity development is their ethnic identity, or how an individual

identifies within or across cultural group(s) (Phinney, 1990). This identification, or ethnic group affiliation, is a particularly formative component to minority adolescents' self-concept (French et al, 2006). Studies have shown the emergence of this process can occur as early as middle school, as adolescents of color actively strive to understand their diverse backgrounds and the possible implications of their group membership (Phinney, 1993). One way adolescents are able to establish their ethnic identity and the importance of cultural labels to their self-concept is through ethnic socialization. Ethnic socialization is defined as the direct and indirect messages an individual receives from others (e.g., parents, peers, authority figures, institutions) that allow them to learn about their own and other ethnic group(s) (Rivas-Drake, 2010). These socialization messages can be expressed positively, thus enhancing ethnic identity development and providing stronger feelings of group belongingness (French et al, 2006). In contrast, negative ethnic socialization messages can severely hinder one's ethnic identity development. For example, families who promote their children's engagement of cultural practices may exhibit positive socialization messages; however, families who detach themselves from their cultural background and show cultural shame express lower levels of ethnic group belongingness.

Ethnic Identity and Psychosocial Well-Being

Previous research has identified many relationships between ethnic identity/ethnic socialization messages and mental health outcomes/behaviors. Positive socialization messages are associated with many healthy adjustments, such as increased academic self-efficacy, resilience, self-esteem, and psychosocial well-being. Negative socialization messages are associated with various detrimental factors, including aversion to ethnic identity exploration, higher levels of mistrust, poorer academic performance, increased externalizing behaviors, and less social competence (Caughy et al., 2006; Hughes et al., 2009; Huynh and Fuligni, 2008; Joseph and Hunter, 2011; Tran and Lee, 2010). While socialization messages are large contributors to the development of an adolescents' ethnic identity, the foundation of a strong ethnic identity has been found to be an extremely influential mediator of such messages through increasing the salience of positive messages and buffering negative messages (Gatner, Kiang, & Supple, 2013). Adolescents who are able to establish a strong ethnic identity are thus more likely to resolve disparities between the positive and negative socialized messages, have higher levels of self-esteem, and experience positive psychological adjustment (Roberts et al., 1999). Youth continuing to struggle with developing their ethnic identity experience race-related stress and, as a result, much lower levels of psychosocial well-being (Iwamoto & Liu, 2010).

Collectivistic vs. Individualistic Cultures

When comparing and contrasting different cultures, researchers frequently observe the presence of collectivistic or individualistic qualities within each culture. The highlighted difference between the two extremes is how active agents within that culture view the self with regards to their community; in other words, individuals who identify with a collectivistic culture are more likely to view themselves as a unit of a greater collective, while individualistic cultures emphasize the importance of an independent self. For example, failure is attributed to a lack of effort in collectivistic cultures and collectivistic-identifying individuals may strive to improve themselves for their community as a result. However, individualistic people are more likely to attribute their failure to external factors (e.g., bad luck, extremely difficult task), thus leading them to remain static in their abilities. Consequently, success in collectivistic cultures is attributed to the surrounding support system, while success in individualistic cultures is predominantly attributed to self-efficacy (Triandis, 1993).

Another differentiating component of collectivistic and individualistic cultures is their geographic locations. Individualistic cultures are more likely found in Western countries (e.g., United States, Australia, Germany), and collectivistic cultures are mainly located in Eastern countries (e.g., China, Vietnam, India). Although previous research does not exhibit a causal relationship between geography and cultural styles, Eastern countries are commonly regarded as more traditional and Western countries as progressive (Triandis, 1993).

Berry's Acculturative Strategies

Cross-cultural research has commonly explored developmental differences through a unidimensional lens by differentiating between collectivistic-identifying and individualistic-identifying individuals; however, these studies give little regard to bicultural persons. Berry (2007) approached cultural research with a bidimensional perspective by incorporating individuals' enculturation (interactions with the heritage culture) and acculturation (integration into other cultures). His research identified a series of acculturative strategies a multicultural individual may utilize to form their ethnic identity: (1) *separation* occurs when one avoids interaction with other cultures and holds strongly onto their heritage culture, (2) *marginalization* occurs when one is neither interested in maintaining cultural roots nor immersing into other cultures, (3) *assimilation* occurs when one does not maintain their heritage cultural roots but instead fully integrates into another culture, and (4) *integration* occurs when one is able to maintain their original culture while interacting with other culture(s).

This bidimensional conceptualization of ethnic identity has proven to be more valid when observing individuals' development compared to traditional unidimensional approaches – specifically, the extent of an adolescents' acculturation is closely related to their psychosocial well-being (Ryder, Alden, & Paulhus, 2000). Bicultural competence, or an integrative acculturation strategy, is hailed as the most adaptive ethnic identity state and yields the most positive psychological adjustment outcomes (Berry, 1997). Youth who utilized this strategy were more likely to possess higher GPAs and levels of self-esteem than their marginalized or separated acculturative strategy counterparts (Farver, Bhadha, & Narang, 2002). While utilizing an assimilated acculturative strategy also seems favorable, previous research has consistently considered it to be less adaptive than an integrated technique. Minority adolescents primarily acculturating within the dominant culture are less prepared to face racial adversity, putting them at a higher risk of suffering from negative consequences of racial discrimination and negative socialization messages – ultimately, this could induce feelings of betrayal and lower levels of in-group identity within the dominant ethnic group (Chae et al. 2012; Park et al. 2013). In contrast, both separated and marginalized acculturative strategies suggest the worst adaptive outcomes for bicultural individuals. Individuals separating themselves from the dominant culture put themselves at a higher risk of unsuccessfully integrating into mainstream society and experiencing acculturative stress. Marginalized individuals experience even more detrimental consequences as they socially and culturally isolate themselves from both their heritage and the dominant culture (Berry, Kim, Minde, & Mok, 1987).

Asian Adolescents

With the joint effect of high immigration rates and advanced medical care, the United States population continues to grow annually. Contrary to popular belief, the United States' Asian population holds the fastest growth rate of any other ethnic group in the country – from 2000 to 2015, the Asian American population grew by 72%, or almost 10 million people. Asian Americans currently only make up 13% of the immigrant population; however, researchers believe high immigration rates for this ethnic group will result in Asian Americans making up almost 40% of the immigrant population in 50 years (Lopez, Ruiz, & Patten, 2017). Asian adolescents have thus become an increasingly popular population of interest when observing what role immigrating to a progressive Western culture from a traditional Eastern culture may have on their ethnic identity development.

In addition to these high immigration rates, Asian Americans hold a unique title in the United States as the "model minority." This perception of Asian Americans encompasses a complex and stereotyped expression of hard work, intelligence, and success. While some may argue being called a "model minority" is positive, this oxymoronic label is still a stereotype and form of negative ethnic socialization. One study conducted by Gupta,

Syzmanski, & Leong (2011) observed a positive association between the endorsement of positive Asian stereotypes and psychological distress in Asian Americans. Therefore, not only do positive stereotypical beliefs allow a subtle means to express racism, but they also deny Asian Americans access to an American ethnic identity – in other words, Asian Americans do not view themselves as less American than their White counterparts, but they are still perceived as less American by other ethnic groups. The incongruence between Asians' viewpoint of their ethnic identities and how other Americans view them brings a distinctive case to research in ethnic identity formation.

Objective of this Report

The formation of ethnic identity is an indispensable component to identity exploration, especially for adolescents of color. In addition to providing social benefits and group membership, an established ethnic identity predicts better psychological adjustment outcomes and higher levels of psychosocial well-being. The differentiation between collectivistic- and individualistic-identifying individuals does not fully encompass the complexity of bicultural persons; however, Berry's acculturative strategies provide an additional dimension to observe an individual's acculturation and enculturation. Asian Americans have and continue to hold the most rapid rate of population growth of any ethnic group in the United States, making them one of the most targeted demographics for cross-cultural research. Their unique position as the "model minority" also facilitates discussion of how their ethnic identity formation can be impaired or enhanced when facing this conflicting cultural label. In this report, I sought to understand how Asian adolescents' acculturative strategies can influence their psychosocial and identity development.

RESEARCH METHODS

I compiled findings from articles investigating Asian immigrant populations in various countries (e.g., America, Australia, Canada, etc.) and their ethnic identity development. Across the research studies, all participants were of Asian descent (including Vietnamese, Korean, Chinese, Japanese, etc.) with ages ranging from 12 to 55 – a majority of the participants were in high school or college. The studies' sample sizes ranged from 83 to 417 participants, with five out of six studies having sample sizes greater than 200.

All of the researchers distributed self-report questionnaires to their participants, measuring self-esteem, ethnic identity, type of acculturation, and psychological well-being. The Suinn-Lew Asian Self-Identity Acculturation Scale and Rosenberg's 10-item Self-Esteem Scale were used in most of the studies. Additionally, two of the research studies conducted interviews on subjects' social experiences, immigrant experiences, and how they adapted to a culturally different world. Findings across all of these studies were integrated to describe psychosocial well-being and behavioral correlates of individuals who are most likely to use each type of acculturative strategy.

SUMMARY OF FINDINGS

Separation

Foreign-born participants were the most likely to utilize a separated acculturation strategy (Miller et al, 2013). In a few of the interviews, the term "FOB," or "fresh off the boat," was used as a racial slur against Asian immigrants. Participants indicated the two main markers of a "FOB" were: (1) speaking with a thick accent and (2) using foreign language in public (Pyke & Dang, 2013). Through self-report questionnaires, separated acculturation strategy users reported having poorer mental health, more acculturative stress, and less positive attitudes towards seeking psychological help than users of any other acculturative strategy (Miller et al, 2013). Although they saw cultural differences as expected and manageable challenges, these participants reported a sense of confusion or difficulty in understanding Western culture. They revealed compartmentalization as their solution to adversity – when being faced with cultural differences, separated strategy users are likely to lean towards their ethnic origins rather than understanding why the mainstream culture is different. (Lieber et al, 2001).

Marginalization

Although all participants resided in the United States for an average of 16 years, the majority of the marginalized group consisted of foreign-born participants. They reported lower levels of acculturative stress compared to those using a separated strategy; however, they still exhibited higher levels of acculturative stress than integrated strategy users (Miller et al, 2013). Subjects felt a sense of inability or reluctance to overcome the challenge of reconciling cultural differences and perceived these differences as unresolvable. Marginalized strategy users also reported a significantly worse overall quality of life compared to any other acculturative method group, as well as feelings of anger, disgust, and alienation (Lieber et al, 2001).

Assimilation

In contrast to separated acculturative strategy users, participants using an assimilated strategy were characterized as "whitewashed," or one who has assimilated into mainstream White culture and retained few ethnic practices. In the interviews, adolescent participants described "whitewashed" Asians as people who cannot or refuse to speak their heritage language, have many non-Asian friends, date non-Asians, behave and dress according to White culture, and/or are unfamiliar with ethnic customs (Pyke & Dang, 2013). While their ethnic counterparts label them as having "forgotten their roots" and believe they are ashamed of their heritage culture, some assimilated individuals took pride in being called "whitewashed" – especially if they placed White culture at a higher status than other cultures. By being identified with the term "whitewashed," assimilated strategy users believe they are avoiding association with racial stereotypes and are achieving superiority over their traditional co-ethnic peers (Pyke et al, 2013).

When confronted with cultural challenges, assimilated strategy users revealed the "inconvenience" of learning new cultural practices; however, they viewed these challenges as expected and manageable with no accompanying negative emotion. Assimilated participants also used a forward-thinking mindset when discussing their immigration experiences, thus expressing their expectations of a successful integration into mainstream culture (Pyke et al, 2013). However, some studies found an inverse relationship between assimilation and self-esteem and between assimilation and psychological well-being (Chae & Foley, 2010; Phinney, Chavira, & Williamson, 1992). The researchers concluded highly assimilated Asian Americans define their self-concept through their ability to assimilate into mainstream American society. This causes them to over-assimilate, or reject and renounce their heritage culture, and develop a deep self-hatred emerging from denial of their ethnic identity. Consequently, over-assimilated Asian Americans will turn their hostility and aggression inward and increase their risk for impaired psychological well-being (Chae et al, 2010).

Integration

Participants who are able to achieve bicultural competence viewed cultural differences as feasible and used compartmentalization as a method to reconcile these differences. They viewed disparities between the dominant culture and their heritage culture as an opportunity to promote positive personal growth (Lieber et al, 2001). Researchers found that integrated strategy users derived direct psychological benefits from holding positive perceptions about their ethnic group (i.e., more happiness and less anxiety). Positive regard towards their ethnic culture served as a long-lasting buffer against daily stressors (Kiang et al, 2006).

Compared to assimilated strategy users, integrated individuals exhibited a positive relationship between self-esteem and integration (Phinney et al, 1992). A similar positive association was found between ethnic identity and psychological well-being, with ethnic identity being positively related to social connectedness and self-esteem; therefore, stronger ethnic identities were related to higher levels of cultural adjustment (Chae et al, 2010).

ANALYSIS OF FINDINGS

Across the different research studies, there were consistent findings regarding each of Berry's (2007) acculturative strategies and how they presented themselves in Asian immigrants. Individuals who asserted a separated acculturation strategy exhibited lower psychological well-being than all other strategies. In one of the study interviews, participants described American culture as too hard and confusing to understand (Pyke et al, 2013). Due to lowered confidence in integrating with another culture, separated Asians may find themselves suspended away from majority culture practices and more deeply in touch with their heritage culture. Commonly discriminated characteristics (e.g., thick accent and use of heritage language) among separated Asian participants could lead to further ostracization, making it more difficult for them to attempt integration, reinforcing their already rigid views in refraining from integration into mainstream White culture. Participants may consequently use a separated acculturation strategy as a protective means against being rejected by the dominant culture (Suh et al, 2020).

Although the literature on marginalized acculturation strategy utilization in Asian adolescents was thin, the findings were consistent with previous research on marginal individuals. The Marginal Man Theory posits that an individual stuck in between two cultural worlds may struggle to fully establish their identity, thus placing bicultural individuals at a heightened disadvantage in identity development processes (Park, 1950). Similar to separated participants, marginalized Asian participants experienced higher levels of acculturative stress and believed they were unable to reconcile cultural differences between both the dominant and their heritage culture. Previous research concluded with similar findings and observed bicultural individuals who interpreted their two cultures as different were more likely to have lowered levels of identification with both cultures (Stroink & Lalonde, 2009). Marginalized Asians may thus possess a sense of American and Asian cultural inauthenticity, or a belief one is not a genuine representation or their presumed culture (No, 2008). The combined effect of identifying as a "marginal man," perceiving both cultures as different, and experiences of cultural inauthenticity could lead to increased difficulty in developing one's ethnic identity.

Contrary to popular belief, assimilation into the majority culture may provide more harmful consequences than benefits. The Social Identity Theory proposes that giving up one's ethnic culture can have a negative impact on their self-concept (Tajfel & Turner, 2004). As discussed previously, "whitewashed" Asians are guilty of over-assimilation into mainstream White culture, thus their renouncement towards their heritage culture may provide insight into their high risk for impaired psychological well-being. Assimilated Asian individuals' absence of a stronger sense of group belonging from their heritage culture puts them at a higher risk of depending their self-worth on their level of acceptance into the dominant culture; in turn, this may lead to more dire consequences if assimilated Asian adolescents are rejected (Tajfel, 1992; S. Sue & Sue, 1971). As a result, assimilation into the majority culture early on without creating a strong fundamental base with one's heritage culture could result in negative effects on an individual's psychological well-being.

Consistent with previous research, individuals who achieve full integration within two or more cultures have reaped more psychological benefits compared to individuals who use other acculturative strategies (Berry, 1997). For example, the analyzed studies observed bicultural Asian adolescents are more likely to experience increased levels of self-esteem and social connectedness, more happiness and less anxiety, and higher levels of cultural adjustment than other acculturative strategy users (Chae et al, 2010; Kian et al, 2006). Previous studies have also found a strong sense of belonging to both one's ethnic group and to the dominant group is associated with a more established ethnic identity, more perceived social support, and greater academic achievement (Liu et al, 2011). Bicultural individuals are also more likely to be resilient than their monocultural counterparts when facing adversity (Sirikantraporn, 2013). In contrast to assimilated acculturative strategy users, integrated Asian adolescents have a well-developed sense of ethnic identity to their heritage culture protecting them from the negative

psychological effects of discrimination (Liu et al, 2011). These derived psychological benefits may stem from integrated bicultural persons' ability to successfully navigate and be flexible in unfamiliar contexts, such as a new culture, thus fostering resilience and positively promoting identity exploration.

CONCLUSION

To conclude, this report highlights the differing effects of acculturation strategies and what social, personal, and environmental factors can influence the development of Asian individuals' ethnic identity and psychosocial well-being. While this report served as a condensed analysis of a few studies, much more research needs to be done on ethnic identity exploration and development in underserved populations, such as Asian American immigrants. It is imperative cultural researchers and policymakers continue to take strides in identifying immigrants' barriers to attaining bicultural competence, as well as creating the necessary interventions to allow successful integration of immigrants into the dominant culture.

LIMITATIONS & FUTURE DIRECTIONS

Although consistent findings were found across the studies, this report is not without limitations. First, while a multitude of Asian cultures (e.g., Korean, Chinese, Japanese, Southeast Asian) were included across all of the studies, it is important to consider a major limitation regarding inclusion of a diverse sample between- and within- Asian ethnic groups – specifically, there was a higher concentration of East Asian individuals across the samples. Second, the generalizability of these samples is low as most participants were not representative of underserved ethnic or low SES populations. Third, while this report sought to observe the effects of acculturative strategies on adolescents specifically, some of the analyzed studies' samples consisted of adults and adolescents. Finally, a majority of the results were correlational; therefore, the researchers were unable to determine the directionality of the relationship between ethnic identity and personal characteristics. For example, a participant who has high self-esteem could increase their confidence by integrating their heritage and dominant culture and, as a result, they feel higher levels of self-esteem due to an increased sense of connectivity to two cultures. In contrast, a participant who holds high levels of confidence may view their cultural differences as manageable and be more likely to achieve bicultural competence. In other words, their positive personal characteristics could cause them to take on an integrative approach to their ethnic identity development.

In addition to these limitations, it must be noted that the acculturative process is dynamic – individuals' pattern of cultural engagement and its effects on their psychological well-being could change over time. Future directions could include: (1) looking longitudinally at Asian immigrants' acculturative strategies and their possible long-term psychosocial effects, (2) comparing generational acculturative strategies and psychological well-being, (3) investigating how one's context shapes/facilitates the acculturation process, (4) measuring the relationship between time spent living in a new country and an individual's acculturation progress, and (5) creating an intervention to increase self-esteem and observe its effects on Asian subjects' ethnic identity.

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About the Author

Lang Duong is a graduating senior from Greenville, NC at the University of North Carolina at Chapel Hill, and she is currently pursuing her Bachelor of Science in Psychology. She became heavily involved in research during the last two years of her undergraduate career through research assistant positions in Dr. Eva Telzer's Developmental Social Neuroscience Lab, Dr. Sam McLean's Heroes Health Initiative app-based study, and others. Lang's UNC JOURney submission came into fruition through her independent research as a part of Dr. Beth Kurtz-Costes' Motivation and Identity Lab. As a daughter of two Vietnamese immigrants, Lang is extremely passionate about researching Asian adolescent development in varying contexts, mental health stigmatization in underserved populations, democratization of psychological resources, and the creation of culturally-sensitive psychotherapy services. She currently has a position as a Karen M. Gil Intern through the Society of Clinical Child and Adolescent Psychology under the supervision of her mentor Dr. Eric Youngstrom – one of her main focuses through this position is on the dissemination of AAPI mental health resources in response to recent Asian hate crimes. She is also applying to post-baccalaureate research positions in psychology labs all over the country and plans to pursue a Clinical or Developmental Ph.D.

Interpersonal Violence & Pregnancy Termination: A Retrospective Study of Women in India

by Morgan Elizabeth Johnson & MacKenzie Ann Mensch

It has been well-documented that many women worldwide will experience interpersonal violence (IPV) throughout their lifetime. IPV is linked to increased rates of miscarriage, stillbirth, and abortion. This connection compels the field of Maternal and Child Health to focus on IPV as a prominent issue affecting women. We performed a retroactive study using data obtained in 2015 by Integrated Public Use Microdata Series-Demographic and Health Surveys (IPUMS-DHS) that describes women in India who have experienced either miscarriage, stillbirth, or an abortion. This allowed us to evaluate the relationship between IPV and change in pregnancy termination types. We suspect that our analyses will align with the well-documented relationship between physical and/or emotional violence, resulting in higher proportions of pregnancy termination. It was observed that there were increased miscarriage and abortion rates for urban and rural communities in the presence of emotional violence. Additionally, increased miscarriage and abortion rates were seen in rural communities in the presence of physical violence. This suggests that pregnancy termination type rates are influenced by the presence of IPV during pregnancy. Given that IPV is a wide-spread problem and affects countless women globally, it is important to investigate what may contribute to these changes in rates of pregnancy terminations to best address the biological and social factors that affect pregnancy outcomes. This synergism between the biological and social spheres indicates that holistic approaches to public health interventions would be the most beneficial.

Keywords: interpersonal violence, pregnancy termination, India, Maternal and Fetal Health, physical abuse, emotional abuse

INTRODUCTION

Interpersonal violence (IPV) is found to be correlative with poor maternal and fetal health outcomes. This can include physical, sexual, emotional, and economic abuse (World Health Organization, 2012). Globally, 35% of women have ever experienced physical and/or sexual intimate partner violence, or sexual violence by a non-partner (World Health Organization, 2013). Additionally, some studies have found that this number could be as high as 70% (World Health Organization, 2013). This variation in reporting is attributed to both regional variability and specific cultural recognition of IPV. Often, cultures may only recognize IPV as physical abuse, which excludes individuals experiencing other forms of abuse (Showalter, 2020). Furthermore, in cultures where IPV is more tolerated, the social climate inhibits and silences survivors (Garcia, 2004). This experience is subsequently translated into a multitude of poor outcomes, such as significant stress, negative health effects, and negative economic effects (Lutgendorf, 2019). Previous research has sought to identify any correlation between experiencing IPV and negative pregnancy outcomes as a means of further understanding additional negative health effects of IPV. Nesari and colleagues found that maternal history of abuse before pregnancy was significantly associated with preterm delivery and low birth weight (Nesari et al., 2018). This has led us to investigate the relationship between IPV and additional poor birth outcomes classified under pregnancy termination.

IPV creates not only a hostile environment but also additional health complications for women who endure this treatment. Current literature cites a multitude of outcomes that can be correlated with the onset of IPV, some of which include an increased risk of unwanted pregnancy, teenage pregnancy, human immunodeficiency virus (HIV), sexually transmitted infections (STI), malnutrition, pregnancy complications, and negative birth outcomes (Speizer & Pearson, 2011). These mis-timed and unwanted pregnancies are often characterized by an external locus of control exacerbated by the experience of violence prior to pregnancy (Dasgupta et al., 2019). Furthermore, women who have experienced violence are less likely to receive antenatal care or home visits by health workers, leading to an increased risk of perinatal and neonatal mortality of 2.37 to 2.59 times higher, respectively, than women who have not experienced violence during pregnancy (Sakar, 2013). These statistics emphasize the notion that IPV has detrimental impacts on the decision-making process regarding receiving prenatal caremade by pregnant mothers, acting as a catalyst for additional

detrimental influences during pregnancy.

Despite the consensus in the current literature surrounding IPV and pregnancy termination, there has yet to be the same degree of focus on low-to-middle-income countries. While there are some similarities in birth outcomes, children born to mothers in low-to-middle-income countries overall have poorer outcomes compared to children born to mothers in higher-income countries (Goldenberg et al., 2018). This disparity between pregnancy terminations in regions of different economic wealth is attributed to a difference in structural systems, economic opportunities, financial independence for women, and socio-cultural beliefs. One of the best-documented disparities in birth outcomes is stillbirth. It has been cited that 98% of stillbirths occur in low-to-middle-income countries globally (Goldenberg et al., 2016). A population-based, multi-country study of stillbirth rates from 2010-2013 found that stillbirth is ten times higher in low-to-middle-income countries than high-income countries (McClure et al., 2015). Stillbirth deaths in low-to-middle-income countries are associated with intrapartum events, such as poor care at delivery. However, in high-income countries, intrapartum stillbirths rarely occur (Goldenberg et al., 2016). These findings propelled our focus to include a low-to-middle income country with a high prevalence of IPV.

One of the most well-cited countries reporting a high prevalence of IPV is India. The World Bank defines low-to-middle-income countries as having a gross national income (GNI) per capita between $1,036 and $4,045 (World Bank Country and Lending Groups). For the 2019 fiscal year, India had a GNI per capita of $2,120 (GNI Per Capita). According to the 2005-2006 National Family Health Survey conducted across India, 40% of women experience some form of IPV. This measurement included physical, emotional, psychological, financial, or sexual abuse during the course of the marriage (Showalter et al., 2020). A systematic review found that across 137 quantitative studies, a median of 41% of women in India reported experiencing domestic violence during their lifetime and 30% in the past year (Kalokhe et al., 2016). However, the WHO reports a global rate estimated at 33%. Additionally, the Eastern Mediterranean Region rate is estimated at 37% (World Health Organization, 2013). This data confirms that IPV is not solely a global burden, also highlighting that women living in India are experiencing IPV at higher levels. This affirms the relevancy of IPV to the study of maternal and fetal house and the need to examine how IPV correlates to maternal and fetal health outcomes. Although India has a higher prevalence of IPV, it is crucial to evaluate the geographic and social diversity of India's states. These differences are evident through cultural norms and standards of living that are unique between regions and, more specifically, between different communities. These variations include differences in socioeconomic development, violent crime rates, women's status, and community literacy rates (Ackerson et al. 2008; Jejeebhoy et al. 2001). These regional and community differences contribute to the question as to why the prevalence of IPV is not consistent throughout the entire country and within nation-states. Previous research has found that the oppressive cultural norms in India, such as the patriarchy and caste system, can be to blame for sustaining the social acceptance and justification of IPV (Kimuna et al. 2013).

However, when breaking down the country's social practices into smaller communities, it has been noted that there is diversity in the cultural norms and standards of gender relations between regions in India, thus contributing to rates of IPV being dependent on geographic location within the region (Kimuna et al. 2013). The regional differences between different states are further exemplified through demographics. Due to the exponential growth of those living in India's urban areas, this has doubled the population of those living in poverty and slum areas. This population increase, combined with the increased poverty, further exacerbates reproductive challenges (Arokiasamy et al. 2013; Showalter et al., 2020). This intersection further justifies our decision to focus on a sample of women from India.

Reproductive rights, female autonomy, and their relationship with IPV act as an example of the regional differences within the country. Historically, a traditional structuralist paradigm has been used to frame IPV within a social, cultural, and historical framework of inequality between the sexes under the "Radical Feminist Theory"

focuses on violence by men in intimate relationships as a result of power differentials that serve to keep the woman subordinate (Saulnier, 1996; Eswaran et al., 2011); therefore suggesting that in areas of lower economic opportunities, a woman's vulnerability is often heightened. This enhanced vulnerability can occur through women's economic dependency on their male partners, the absence of female participation in the labor force, and lack of education (Dalal, 2011). Subsequent power differentials often negate the protective factor of living in an urban setting versus a rural setting (Showalter et al., 2020), thus reinforcing the need to examine educational attainment when looking at our data set. It has also been well-documented that factors related to severe physical violence and injuries include rural residence (Sabri et al., 2014). This is often attributed to reduced educational attainment on average and increased social norms that work to reduce women's empowerment and autonomy.

Furthermore, women's economic dependency on their male partners is exasperated when young girls enter a marriage. Previous studies conducted in India concluded that age at marriage is correlative to IPV, concluding that older age is a protective factor against this form of punishment (Speizer & Pearson, 2011). This coincides again with the framework of the Radical Feminist theory when considering inequality between sexes, which is heightened in a marriage dynamic with a wide age gap. Subsequent well-documented protective factors include women's education and working in agriculture (Hindin et al., 2008). Interestingly, women's education is not the only role that education takes in functioning as a protective factor. It has been found in Bangladesh that women who lived in communities where men had greater access to education were less likely to experience violence (Hindin et al., 2008). While this has not been well-documented in India, this insight provides an additional example of the interplay between economic opportunities and independence on the prevalence of experiencing IPV. Additional factors that have been seen to increase the prevalence of experiencing violence during pregnancy are behavioral-based. This includes husbands' problem drinking, jealousy, suspicion, and control (Sabri et al., 2014). These factors are seen to enhance emotionally and sexually abusive behaviors and were also related to an increased likelihood of women experiencing severe IPV and injuries. Behavioral-based risk factors are not only seen on an individual level but can additionally be exacerbated by the community and society-level beliefs. Another important risk factor is the adherence to social norms that accept husbands' violence (Sabri et al., 2014). These relationships outline the precedent that there are many external factors unrelated to a woman's history working to enhance the possibility of ever experiencing violence during pregnancy. This again illustrates how the Radical Feminist theory is applicable, given that it coincides with the social, cultural, and historical context. The patriarchy is sustained in this way, thus upholding high rates of IPV.

Additionally, IPV acts as an example of structural violence. Structural violence seeks to describe social injustice perpetuated by the social machinery of oppression. The injury caused to people is a form of violence as a result of social structures that appear invisible, yet they put individuals in harm's way due to an unequal distribution of power and resources (Farmer et al., 2006). While one could argue that this conceptual model is not applicable to this body of research, given its focus on physical or emotional violence versus structural, this is not the case. It has become increasingly apparent that the risk factors for IPV are consistent with the risk factors seen to exacerbate poor maternal and fetal health outcomes through structural violence in the absence of IPV. Risk factors that increase poor maternal and fetal health outcomes include educational attainment and access to living wages (Dalal, 2011). Combined with the factors that have already been discussed, such as lower educational attainment and socioeconomic status, this corresponds to the cyclical nature of structural violence. Additionally, the societal construction of gender infiltrates the perception of people and

their overall access to resources and health. The construction of gender is intimately related to gender equity, female autonomy, and decision-making power. It has been inextricably linked to gender stereotypes that negatively influence women's health, thus increasing a woman's vulnerability to experiencing emotional or physical violence (Rahman et al., 2013). This suggests that gender stereotypes function within the framework of structural violence. The focus of a conceptual model for structural violence highlights the notion that while it is important to remember there are certain things within one's control, oftentimes many risk factors are exacerbated by influences beyond the individual's control. While individual health behavior is important, there are limits to how much an individual can control their own outcomes. This is a theme we should keep in mind, given that women of certain backgrounds are considered at a higher risk of experiencing IPV over their lifetime and during pregnancy compared to others.

Given the documentation of poor maternal outcomes when exposed to violence during pregnancy, we sought to examine the relationship between experiencing physical and/or emotional violence during pregnancy and the prevalence of termination of pregnancy. It has been found that women with a history of violence were more likely to report ever having had an abortion, miscarriage, or stillbirth than those without such a history (Hindin et al., 2008). That being said, the current literature overlooks the potential of a statistically significant relationship between changes in types of pregnancy termination outcomes in the presence of emotional and/or physical violence. Given the current literature, we suspect that the prevalence of physical and/or emotional violence experienced during pregnancy will result in higher proportions of pregnancy termination types. We hypothesize that stillbirth, miscarriage, and abortion rates will increase in the presence of emotional or physical violence. We expect this increase to strengthen when considering the covariates of lower education levels, residing in a rural area, and younger age at delivery.

METHODS

In order to conduct our analysis, we performed a retroactive study using data obtained by IPUMS-DHS. The data we used for our analysis was conducted in 2015, our sample size (N= 3605) included women living in India between the ages of 15 through 49, with age being broken down into five-year intervals provided by the dataset. For this study, we excluded women from the data who had never been pregnant and those with missing data responses. Since IPV can include both physical and emotional abuse, our independent variables included having experienced any form of physical violence during pregnancy and having experienced emotional violence during pregnancy. This variable was derived from the domestic violence module and described physical violence as "hit, slapped, kicked or anything else to physically hurt you" (National Family Health Survey, 2015). Additionally, the domestic violence module, administered by the National Family Health Survey, described emotional violence as "humiliation, insults, and threats of harm." We additionally used education level, age, and urban/rural residence as independent variables. Our dependent variables are the three pregnancy termination types: abortion, stillbirth, and miscarriage. Our analysis created new variables in our data set for each of these three outcomes.

In order to observe the relationship between our independent and dependent variables, we conducted various tests including contingency analysis, chi-square tests, multinomial logistic regressions, and ANOVA regression. The purpose of our chi-square test was to measure whether any relationship existed between physical and emotional violence when tested against our pregnancy termination outcomes. The multinomial logistic regression tested for the probability of our different pregnancy termination outcomes when tested against our independent variables. Additionally, the ANOVA regression tests the change of the mean probability of our three pregnancy termination outcomes in the presence of emotional or physical violence. Significance was determined using the Person's p-value coefficient. A value was deemed statistically significant if it was less than 0.005. In our analysis, we included education level and age as covariates, as these factors can have an influence on our independent variables. In order to make our test more precise, it was imperative to incorporate these variables to account for their ability to skew our test results. Education level was broken down into the following categories: no education, primary education, secondary education, and higher education.

RESULTS

Descriptive Statistics

We found proportions for the entire sample across the categories of types of pregnancy termination, presence of physical or emotional violence, education level, and age (Table 1). We found that overall, the pregnancy termination type with the highest prevalence was a miscarriage at 59.584%. This trend is seen again after dividing the data into urban and rural. We found that 5.298% of the sample experienced physical abuse during pregnancy, and 17.115% experienced emotional violence during pregnancy. When classifying the sample into the categories of rural and urban, individuals living in rural areas had higher proportions of both physical and emotional violence at 5.600% and 17.800%, respectively. We divided our data between three age groups of 15-19, 20-29, and 30-49. Our sample indicated that 57.975% of women were in the 20-29 age group category. We found that 25.104% of the sample had no education attainment, 14.979% had only primary education, 48.793% had only secondary education, and 11.123% had higher education (Table 1).

Table 1. Descriptive Statistics

	Overall		Urban		Rural	
	n	Proportion	n	Proportion	n	Proportion
Stillbirth	322	8.932%	89	7.80%	233	9.40%
Miscarriage	2148	59.584%	670	58.80%	1478	60.00%
Abortion	1135	31.484%	380	33.30%	755	30.60%
Physical Violence During Pregnancy	191	5.298%	53	4.65%	138	5.60%
Emotional Violence During Pregnancy	617	17.115%	177	15.50%	440	17.80%
Age (15-19) (CODE: 20)	43	36.616%	10	0.78%	33	1.33%
Age (20-29) (CODE: 30 - 40)	2090	57.975%	631	56.0%	1459	59.0%
Age (30-49) (CODE: 50-80)	1472	40.832%	498	43.10%	974	38.90%
No Education	905	25.104%	171	15.0%	734	29.80%
Primary Education	540	14.979%	148	13.00%	392	15.90%
Secondary Education	1759	48.793%	598	52.50%	1161	47.10%
Higher Education	401	11.123%	222	19.50%	179	7.30%

Multinomial Logistic Regression

Table 2 shows the results from our multinomial logistic regression for urban communities and rural communities. After running various multinominal logistic regressions, the results indicated that urban communities had a higher proportion of individuals who would experience a miscarriage after having experienced solely physical violence during pregnancy. In urban communities, this proportion is 0.647 compared to the rural proportion of 0.492. However, rural communities had higher proportions for abortion at 0.342 in comparison to 0.274 for urban communities (Table 2). When combining both physical and emotional violence prevalence during pregnancy, the probability of experiencing a miscarriage was the highest amongst the three pregnancy termination types in both urban and rural communities at 0.560 and 0.481, respectively. Additionally, our results indicated that rates of miscarriage when excluding physical and emotional violence were higher in rural communities (0.609) compared to urban counterparts (0.600). Rates of abortion were higher in urban communities (0.321) with respect to rural communities (0.294) (Table 2).

Table 2. Multinomial Logistic Results for Urban and Rural Communities

	Urban			Rural		
	Miscarriage	Abortion	Stillbirth	Miscarriage	Abortion	Stillbirth
Only Physical Violence During Pregnancy	0.647	0.274	0.078	0.492	0.342	0.166
Only Emotional Violence During Pregnancy	0.509	0.418	0.073	0.590	0.344	0.000
Both Emotional and Physical Violence During Pregnancy	0.560	0.395	0.074	0.481	0.404	0.115
Neither Emotional nor Physical Violence During Pregnancy	0.600	0.321	0.079	0.609	0.294	0.097

One-way ANOVA Regression

Table 3 shows the results for the One-way ANOVA regression, separated by our variables of the presence of physical violence and the presence of emotional violence for the overall sample, those in rural communities and those in urban communities, and the effect on pregnancy termination type. After running a One-way ANOVA analysis without categorizing the data by community, we found a p-value of 0.00140 in the presence of emotional violence, thus indicating our results were statistically significant when rejecting the null hypothesis in instances where $p<0.005$. This concludes that the mean proportions of the experiencing pregnancy term types are different when emotional violence is accounted for. (Table 3). However, these results were not significant when analyzing the effect of the presence of physical violence during pregnancy and the means of our pregnancy term outcomes at a p-value of 0.624 (Table 3). Our results from the One-way ANOVA analysis were indicative of a statistically significant association at a p-value of 0.00850; therefore, the mean values for our pregnancy term outcomes were different for rural communities (Table 3). However, this same test was not statistically significant for urban communities at a p-value of 0.0556 (Table 3). Our One-way ANOVA analysis yielded statistically insignificant results at p-values of 0.913 and 0.578, respectively, when examining the effect of physical violence during pregnancy and the mean values of our pregnancy term outcomes, indicating that the mean values are not related (Table 3).

Table 3. One Way ANOVA

Source	DF	Sum of Squares	Mean Square	F-Ratio	Prob > F
Emotional Violence During Pregnancy					
Overall	1	359.11	359.107	10.1874	0.0014*
Error	3603	127006.11	35.250		
C. Total	3604	127365.21			
Urban	1	126.998	126.998	3.6706	0.0556
Error	1137	39338.323	34.598		
C. Total	1138	39465.320			
Rural	1	246.671	246.671	6.9460	0.0085*
Error	2464	87503.694	35.513		
C. Total	2465	87750.365			
Physical Violence During Pregnancy					
Overall	1	8.52	8.5199	0.2410	0.6235
Error	3603	127356.70	35.3474		
C. Total	3604	127365.21			
Urban	1	0.417	0.4172	0.0120	0.9127
Error	1137	39464.903	34.7097		
C. Total	1138	39465.320			
Rural	1	11.016	11.016	0.3094	0.5781
Error	2464	87739.349	35.6085		
C. Total	2465	2465	87750.365		

Contingency Analysis

Our results for the contingency analysis can be found in Tables 4-6. The contingency table between the presence of physical violence and pregnancy term type indicates a p-value of 0.0448, indicating a small significance. These results also allow us to reject the null hypothesis, indicating that the presence of physical violence and pregnancy term type is not exclusive. When investigating the relationship between education level and experiencing physical violence during pregnancy, the relationship was deemed statistically significant with a p-value of less than 0.0001 (Table 4).

Additionally, we ran a contingency analysis between each pregnancy term outcome and the covariate, education level. These results have been compiled into Table 5. When looking at education level and pregnancy term outcome, abortion, and stillbirth had statistically significant p-values of less than 0.001, while miscarriage had a p-value of 0.957. These results show a statistically significant outcome between education level and the proportion of women who reported an abortion. Significance was also found between education level and the proportion of women who reported a stillbirth. In order to get a deeper understanding, we broke these results down by community type located in Table 6.

Table 4. Contingency Results Between Education Level and Experiencing Physical Violence During Pregnancy

Test	Chi-square	Prob>ChiSig
Likelihood Ratio	28.012	<0.0001
Pearson	28.227	<0.0001*

Table 5. Contingency Results Between Education Level and Pregnancy Term Outcome

Pregnancy Termination Type	Test	Chi-square	Prob>ChiSig
Abortion	Likelihood Ratio	23.805	<0.0001
	Pearson	23.207	<0.0001*
Miscarriage	Likelihood Ratio	0.316	0.9569
	Pearson	0.316	0.9569
Stillbirth	Likelihood Ratio	70.380	<0.0001
	Pearson	76.766	<0.0001*

Table 6. Contingency Results Between Education Level and Pregnancy Termination Outcome Broken Down By Community Type.

Pregnancy Termination Type	Urban			Rural		
	Test	Chi-square	Prob>ChiSig	Test	Chi-square	Prob>ChiSig
Abortion	Likelihood Ratio	4.586	0.2048	Likelihood Ratio	21.988	<0.0001
	Pearson	4.537	0.2090	Pearson	21.738	<0.0001*
Miscarriage	Likelihood Ratio	1.252	0.7406	Likelihood Ratio	0.859	0.8353
	Pearson	1.246	0.7419	Pearson	0.859	0.8354
Stillbirth	Likelihood Ratio	9.596	0.0223	Likelihood Ratio	64.783	<0.0001
	Pearson	11.099	0.0112*	Pearson	65.325	<0.0001*

After taking into account whether an individual lived in an urban or rural community, our contingency result showed a statistically significant relationship between education level and the proportion of reported stillbirths in urban and rural communities. In urban communities, the p-value for the relationship between stillbirth and education type is statistically significant at 0.0112, but statistically significant at less than 0.0001 in rural communities. A statistically significant relationship was also prevalent when looking at education level and the proportion of abortions reported in rural communities. In urban communities, the p-value for the relationship between abortion and education type is 0.209, while it is statistically significant at less than 0.0001 in rural communities. A statistically significant relationship was not prevalent when looking at education level and miscarriage in either rural or urban communities. In urban communities, the p-value for the relationship between miscarriage and education type is 0.742 and 0.835 in rural communities.

According to our contingency table, the relationship between the presence of physical violence during pregnancy and pregnancy term type yielded a p-value of 0.0148 in rural communities. This indicates a significant relationship between these two variables since the p-value is less than our significance measure of 0.005. After separating pregnancy termination type into the three individual categories (miscarriage, abortion, and stillbirth), the contingency table for rural populations showed a significant relationship between the presence of physical violence and the proportion of women who experienced a miscarriage with a p-value of 0.005. However, the results indicated a small significance in which the probability of a female reporting a miscarriage was greater when declining ever experiencing physical violence during pregnancy.

Logistic Regressions

Table 7 represents the results from our logistic regressions. After running a logistic regression between age in 5-year intervals and the presence of physical or emotional abuse during pregnancy, our results showed no statistically significant relationship (Table 7).

Table 7. Logistic Regression Results Between Age in 5 Year Intervals and Experiencing Violence

Term	Estimate	Std error	Chi-square	Prob>ChiSq
Emotional Violence				
Intercept	1.67	0.176	90.30	<0.0001*
AGE5YEAR	-0.002	0.004	0.30	0.5812
Physical Violence				
Intercept	2.67	0.296	81.27	<0.0001*
AGE5YEAR	0.004	0.007	0.54	0.4639

Chi Square

Table 8 shows our results from our chi-square analysis. Our chi-square test indicated a significant relationship between both physical and emotional violence during pregnancy and miscarriage in rural communities. From this result, we were able to conclude that some relationship exists between these variables and experiencing a miscarriage. Furthermore, when looking at the effect of emotional violence during pregnancy on abortion, our chi-square results were indicative of an association between emotional violence and abortion in both urban and rural communities. These tests also indicated that both of our independent variables (i.e.: emotional and physical violence) have a statistically significant effect on pregnancy term outcome.

Additionally, our chi-square test concluded statistical significance in the interaction between physical violence during pregnancy and miscarriage; therefore allowing us to reject the null hypothesis that no relationship exists. Contrastingly, the relationship between physical violence and abortion proved to be insignificant in both rural and urban communities. Our results indicated that the probability of a woman experiencing an abortion was higher when answering in the affirmative of having experienced physical violence during pregnancy in rural communities. The insignificance of enduring physical violence at any time during pregnancy and the proportion of women who experienced a stillbirth was also applicable to both urban and rural communities.

Table 8. Chi-Square Results

Chi-Square Test Description	P-value
Stillbirth	
Physical violence during pregnancy in urban areas	0.9406
Physical violence during pregnancy, rural	0.0912
Emotional violence during pregnancy, urban	0.7987
Emotional violence during pregnancy, rural	0.1134
Miscarriage	
Physical violence during pregnancy in urban areas	0.9598
Physical violence during pregnancy, rural	0.0054*
Emotional violence during pregnancy, urban	0.0452*
Emotional violence during pregnancy, rural	0.1736
Abortion	
Physical violence during pregnancy in urban areas	0.0266*
Physical violence during pregnancy, rural	0.0162*
Emotional violence during pregnancy, urban	0.9246
Emotional violence during pregnancy, rural	0.0686
Type of Pregnancy Termination	
Emotional violence during pregnancy, urban	0.9940
Emotional violence during pregnancy, rural	0.0170*

Our analysis did not yield a significant result for either urban or rural communities when testing the relationship between women who experienced a stillbirth and individuals' ever-enduring emotional violence during pregnancy. The relationship between experiencing emotional violence and the proportion of women who experienced an abortion was statistically significant for urban and rural communities, as both p-values were less than 0.005. Additionally, our results showed that the probability of women who experienced an abortion in both urban and rural communities was greater if a woman experienced emotional violence during pregnancy. Our chi-square test indicated a significant relationship between both physical and emotional violence during pregnancy and miscarriage in rural communities. From this result, we were able to conclude that a relationship exists between these variables and experiencing a miscarriage. Furthermore, when looking at the effect of emotional violence during pregnancy on abortion, our chi-square results were

indicative of a relationship in both urban and rural communities. It is also interesting to note, however, that rates of miscarriage when excluding physical and emotional violence were higher in rural communities compared to urban ones, while rates of abortion were higher in urban communities with respect to rural communities. These tests also indicated that both of our independent variables (i.e.: emotional and physical violence) have a statistically significant effect on pregnancy term outcome.

DISCUSSION

Our findings support that pregnancy termination type and experiencing emotional violence have some relationship; however, we were unable to establish a significant relationship between the presence of physical violence during pregnancy and our pregnancy term outcomes. On the contrary, we were able to conclude a significant relationship between emotional violence and pregnancy termination, in general, without controlling for residency status. This result is consistent with the current literature citing that pregnancy termination (miscarriage, abortion, or stillbirth) is significantly associated with having ever experienced IPV during pregnancy (Hindin et al., 2008).

Abortion

We found a significant relationship between experiencing emotional violence and abortion rates for urban and rural communities, but not for physical violence. We found that the probability of women who experienced an abortion in both urban and rural communities was greater if the woman experienced emotional violence during pregnancy. Our results illuminate how living in a rural location is a risk factor for pregnancy termination compared to women who live in urban areas in India. Alternatively, there is a documented relationship between induced abortion and unwanted pregnancies. In a longitudinal study in North India, it was found that 30 percent of births were classified as unintended prior to childbirth. This study concluded that unintended pregnancies were associated with induced abortion, despite legal consequences (Dutta et al. 2015), Additionally, women who experience physical violence from their husbands are significantly less likely to adopt contraception and more likely to experience unwanted pregnancy in rural India (Stephenson et al., 2008). While this does not specifically support emotional violence being associated with unwanted pregnancies, this supports the possible relationship between abortion rates and emotional violence. Based on this current literature, we hypothesize that we will see a similar relationship between emotional violence and contraceptive use. This aligns with the high rates of both IPV and unwanted pregnancies for women in rural India.

Miscarriage

After classifying the data into rural and urban, we found a significant relationship between the presence of physical violence and the proportion of women who experienced a miscarriage in rural areas. Additionally, we found that emotional violence affects the rate of miscarriage for women in both urban and rural areas. This coincides with current literature, adding additional evidence for the argument that rural residency is a risk factor for IPV (Sabri et al., 2014). However, we found a small significance where the probability of miscarriage was greater in the absence of physical violence during pregnancy. This suggests that while physical violence is linked to increasing rates of pregnancy termination overall (Hindin et al., 2008), it should not be taken as the sole contributor to miscarriage rates. Previous research has found that the risk of miscarriage was significantly higher for women with a history of exposure to psychological stress (Qu et al., 2017). The importance of stress on pregnant women offers an example of the relationship emotional violence plays on miscarriage rates. By experiencing emotional violence, stress levels could increase, resulting in the increase of possibility of experiencing a miscarriage. At the same time, miscarriage rates would also be attributed to biological complications. These complications include antepartum and intrapartum causes (Newtonraj et al., 2017).

Stillbirth

We found an insignificant relationship between change in rates of stillbirth in the presence of physical violence for both urban and rural regions. This could be attributed to the biological complications that occur during pregnancy that result in adverse pregnancy outcomes. It has been documented that India ranks first in the absolute number of stillbirths at the rate of approximately 16/1000 births. Risk factors that can increase the chances of a stillbirth delivery include higher maternal age, vaginal delivery, induced labor, preterm delivery, and smaller household size (Newtonraj, et al. 2017). These are possible explanations as to why stillbirths remain high, despite the insignificant relationship between both stillbirth and physical violence and emotional violence and stillbirth.

Education

Women in our sample from rural communities had higher rates of having experienced physical violence, as well as emotional violence. The difference in these proportions compared to women in urban communities can be attributed to differences in social and cultural perceptions. This is exemplified as India becomes more modern due to an increase in economic power, resulting in increased educational opportunities for both men and women. As education increases, self-image and social perception of women additionally increases. This propels women to see themselves as equals to their male counterparts, ultimately reducing the prevalence of IPV (Boyle et al., 2009). An increase in education is also linked to an increase in socioeconomic well-being, allowing women to be more financially independent from their abusive partners. This financial freedom could lead to women leaving abusive environments, encompassing an increase in female autonomy on multiple levels. Using education as a new form of power, women could also be less tolerable of IPV as an acceptable form of "conflict resolution" (Boyle et al., 2009).

When examining the effect of educational attainment, we saw significant differences in rates of pregnancy termination types. Our results showed a statistically significant relationship between education level between the proportion of women who reported an abortion. The relationship between education level and the proportion of women who reported a stillbirth was also signficant. This coincides with the well-documented protective factor of living in areas with greater educational opportunities for both men and women and is consistent with our hypothesis (Hindin et al., 2008). Our results also showed a statistically significant relationship between education level and the proportion of stillbirths in urban and rural communities. Additionally, there was a significant relationship when examining the relationship between education level and rates of abortions reported in rural communities. This corresponds with previously cited literature surrounding the relationship between fertility, education, and female autonomy. With increasing education, fertility rates have been seen to decrease as female autonomy increases. As females gain more freedom to make their own choices, contraception use increases. These factors have been shown to increase education. (Visaria 1993). By increasing education and female autonomy, the negative impacts of unwanted pregnancies could decrease leading to reduced levels of abortion and stillbirth.

We saw no significant relationship between age in 5-year intervals and the presence of physical or emotional abuse and change of rates of pregnancy termination. While it is well-documented that age can function as either a protective factor or risk factor (Showalter, 2020), there is also literature that has been unable to make this same conclusion. This is indicative of the subjectivity of the region in which the study is being done, emphasizing a more individual approach to intervention methods rather than generic assumptions. This suggests that age may be exclusively a risk factor for IPV, and not a risk factor for increased rates of pregnancy termination types for our sample.

INTERVENTION RECOMMENDATIONS

In 2006, India passed the Protection of Women Against Domestic Violence Act, which amended the previous definition of IPV to include "physical, sexual, emotional, verbal, and economic abuse" (Showalter, 2020). While this piece of legislation was a step in the right direction, women in India in both urban and rural communities are experiencing sustained physical and emotional violence. The prevalence of these forms of abuse is attributed to the cultural

patriarchy that places women into submissive roles in India outlined by Radical Feminist theories, highlighting the cultural superiority of males as the "root cause of IPV" (Showalter, 2020). Our research shows a significant relationship between education level and experiencing an abortion in rural communities and stillbirth in urban and rural communities. Given these differences, we suggest intervention approaches based specifically on individual communities rather than a generic community-wide approach. One intervention plan is implementing literary groups in individual towns as a means to increase educational access for women, additionally increasing autonomy. Increasing education levels, autonomy, and subsequently empowerment has been cited as a plausible method in the fight to decrease IPV (Sakar, 2013). Furthermore, increasing education and literacy rates have also been cited as a means to strengthen the acceptance of women's equality. As more individuals collectively adopt a more liberal ideology, scholars hypothesize that the patriarchy could be torn down. Scholars also note that increasing education has been linked to an increase in public health as a whole (Boyle et al., 2009). Additional intervention methods could also focus on spreading IPV reduction messaging, increasing awareness that IPV includes more than just physical violence (Dasgupta et al., 2019).

Additionally, health intervention plans should focus on improving maternal access to neonatal and prenatal care as a means of decreasing adverse pregnancy outcomes. As previously stated, women who experience IPV have less access to vital childcare during their pregnancy, highlighting an unmet medical need. This access could be restricted by financial restrictions due to economic abuse from a partner or an inability to make autonomous decisions due to cultural teachings of male superiority and fear. In order to reduce this gap, intervention plans could train local women on the basics of neonatal care that would allow them to circulate this information and perform home check-ups on local townswomen. This intervention plan is especially prominent in rural areas in which many individuals live in poverty due to a low socioeconomic status; therefore creating financial stress on paying for neonatal care and increasing the possibility of experiencing IPV (Sabri et al., 2014).

In considering these interventions, it is important to remember that in order to complement our findings with appropriate next steps, gender inequity plays a large role in societal factors that sustain IPV within communities. Additionally, when considering gender as a social determinant of health, it will be difficult to undo discriminatory practices (whether in education or health care settings) that sustain structural violence.

LIMITATIONS

While we were able to investigate the variables of physical and emotional abuse, we were unable to account for other forms of IPV, such as economic abuse or sexual abuse. Despite finding statistically significant relationships between pregnancy termination type and experiencing IPV, we were unable to control for biological causes of stillbirth and miscarriage. Given the complexity of pregnancy, it should be noted that there are natural processes that could result in a stillbirth or miscarriage unrelated to the presence of physical or emotional violence. Additionally, there are reasons a woman may seek an abortion that is also unrelated to experiencing emotional and physical violence. In seeking to best analyze our sample by age groups, the grouping of age into five-year intervals could have created limitations. This grouping could have yielded an insignificant test for the wide scope of ages included. Additionally, although age at first marriage has been cited as a predictive factor in IPV prevalence (Speizer & Pearson, 2011), our data did not specifically study the age of our sample population at first marriage. Being unable to break age down into one-year increments to see the correlation between age and our independent variables could provide an explanation as to why these results differ from other studies pointing to age as a predictive factor in experiencing IPV. It has also been

documented that rates of IPV vary across India's 29 different nation-states (Showalter, 2020). Our data was limited to categorizing women into the binary categories of urban and rural which does not permit analysis considering differences between specific nation-states.

CONCLUSION

Our findings showed that there is a statistical relationship between IPV and change in rates of pregnancy termination, albeit dependent on geographic location and educational attainment. This could be attributed to the chronic stress related to experiencing IPV, especially if this is coupled with other socioeconomic factors that are seen to exacerbate IPV. Chronic stress has been well-documented with the prevalence of miscarriages (Qu et al., 2017) and the prevalence of stillbirths (Wisborg et al., 2007). When a woman experiences chronic stress, whether, through IPV or other factors, this can increase the amount of stress internalized by the body and thus lead to a higher prevalence of unfavorable pregnancy outcomes. Maternal stress leads to increased release of cortisol and maternal placental cortisol releasing hormone (CRH). This is associated with preterm labor, preterm delivery, and fetal growth restriction (Pike, 2005). This illuminates the intersection between chronic stress and the risk of poor pregnancy outcomes and pregnancy termination and provides a possible explanation as to why there are statistically significant relationships between the presence of physical or emotional violence and pregnancy termination type. Further investigating this intersection would give providers and policymakers a more informed scope of intervention. Furthermore, our results were more reflective of the lived experiences of women in the sample when looking at the layers of social factors that affect the prevalence of IPV. Additionally, we identified significant relationships between emotional violence and miscarriage and abortion rates for urban and rural communities, as well as significant relationships between physical violence and miscarriage and abortion rates in rural communities. We saw more relationships when controlling for educational attainment. These results highlight the significance of taking social determinants of health, like geographic residency and education, into consideration. By recognizing the influence of these factors, more information on the specific differences between urban and rural communities becomes available. In doing this, we can begin to make the most informed policy recommendations and best mold the field of maternal and fetal health to accommodate for these significant relationships.

Given the significant impact of the influence social factors have on maternal health, further research should be gathered to gain an in-depth understanding of the various perspectives of women's education and autonomy within these two communities. Our research emphasizes the notion that intervention methods should be structured specifically to the community in which they are intended to serve, rather than capitalizing on a "one-size-fits-all" ideology. The prioritization of individual intervention programs is apparent through the discussed impact residency and education have on IPV. Additionally, this research reiterates the negative effects patriarchal cultural norms have on reproductive health. The outlined entanglement of interpersonal violence, education and age, biologic complications, and pregnancy termination outcomes epitomizes the justification for holistic intervention methods designed to address social determinants of health.

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The Incidence and Prevention of Catastrophic Injuries in Track and Field Due to Falls from Same and Different Levels: Applications of Haddon's Injury Prevention Countermeasures and Matrix

by Christina Vu

Context: Track and field is a popular sport for male and female athletes. Commonly thought to have lower injury rates than other sports, catastrophic injuries still occur. Targeted prevention measures can be formed by identifying risk factors. Objective: The incidence of catastrophic injuries from falls among high school and collegiate track and field athletes were described. Specific cases were selected and analyzed to identify injury reduction strategies. Methods: Catastrophic falls were collected from the National Center for Catastrophic Sport Injury Research (NCCSIR) from 7/1/1982 to 6/30/2019. Twelve catastrophic injuries were selected for their similar mechanism of injury and detailed injury report. Cases were analyzed using Haddon's matrix and countermeasures. Results: Over 37 years, 61 catastrophic injuries from falls in track and field were captured among college and high school athletes. The majority of catastrophic falls were from a height (89%) during competition (53%) or practice (46%) and among male athletes (93%) and in high school (72%). All fatal and disabling injuries and 80% of head/skull injures were among pole vaulters. Countermeasure analyses of the 12 cases selected indicated ensuring quality care post-injury, utilizing protective equipment, and modifying hazards to decrease risk were the most relevant to prevent or reduce injuries. Conclusions: Though catastrophic falls in track and field are infrequent, determining targeted countermeasures could reduce the incidence and severity of catastrophic falls. Early recognition and implementation of an emergency action plan, an onsite athletic trainer, and activation of EMS and definitive medical care are critical for preventing death and disability.

Keywords: injury prevention, surveillance, catastrophic, track and field, Haddon's matrix, Haddon's ten countermeasures

INTRODUCTION

Track and field is one of the oldest and most popular sports. Between 7/1/2009 to 6/30/2019, by participants, track and field was the most popular sport for high school women and the second most popular for high school men just behind football. [1] While track and field is commonly thought to have a low incidence of catastrophic injury compared to other sports in high school and college, [2,3], catastrophic injuries to the head [4], spine and internal organs still occur and have substantial impacts on the athletes who sustain them. [5] In general, catastrophic injuries are associated with and often receive more attention in contact sports like football. [6] However, catastrophic injuries have been reported in both jumping and throwing events. [2,3,5,7,8] From 1982 to 2019, the National Center

for Catastrophic Sport Injury Research (NCCSIR) captured 85 direct catastrophic injuries in track and field. [3] A direct catastrophic injury was defined as any severe injury sustained during a school or college sponsored sport that resulted in death, permanent disability, or temporary disability with full recovery. [3] Historically, pole vault has been associated with the majority of catastrophic injuries in track and field which has led to multiple rule changes in the event. [2,5,9] The pole vault injury rate was similar to the catastrophic injury rates of high school football and gymnastics over the same 30-year period. [2]

Despite popularity, there are few epidemiological studies on injuries in track and field.8 Previous research of all high school

and collegiate sports includes injury rates in track and field as a part of an overall comparison of different sport injury rates rather than a sole focus on track and field. [2,3] The few studies exclusively about track and field injuries either emphasize acute injuries, [11] describe injury and prevention in specific events such as pole vault [5,9] and throwing events, [7] or limit injury analyses to high school and collegiate injuries that were severe enough to require emergency transport [12] or were seen at an emergency department. [13] Rather than highlighting acute and overuse injuries, the current study describes 61 catastrophic traumatic injuries in track and field due to falls in high school and college that were collected between 1982 and 2019. Of these catastrophic injuries, specific cases were selected and analyzed to identify possible injury reduction strategies for each event.

Dr. William Haddon used the core belief that injury control can be mitigated by modifying the energy transfer among host (person affected), agent (energy transferred to the host), and environment (contributing physical and social characteristics to the occurrence) to form what is known as the Haddon matrix. [14] These elements are influenced by the three stages of injury (pre-event, event, and post-event); and together, are used to identify potential risks due to energy transfer at specific points in time during the event in order to design overall injury reduction strategies. [14] Haddon also formed what is known as Haddon's ten countermeasures which addresses injury control, but from a different perspective than the matrix. Haddon intended to further understand the relationships among hazards by using classification groups. [15] Each of the countermeasures identify a general injury reduction strategy to guide the formation of prevention strategies for specific events. [14] Both of the Haddon models are useful frameworks to examine events systematically from the perspective of risk factors and to devise plans for injury reduction interventions. [15] Injury reduction is important because the inherent limits of nature make it impossible to completely eliminate injuries, but reduction still remains achievable. [16] Further, catastrophic injury reduction is especially imperative because these injuries typically deal with lifelong injuries or death. [4] Each seemingly small intervention on the epidemiological factors will have a significant reduction effect in the overall injury outcome. [17] In this study, Haddon's ten countermeasures were used to construct general procedures for minimizing catastrophic injuries in pole vault, high jump, and javelin throw and an overall strategy for preventing and reducing catastrophic injuries in pole vault was designed using the Haddon matrix.

METHODS

NCCSIR operates a surveillance system of severe sport-related injuries and medical conditions by tracking cases through a systemic data reporting system. The overall goal is to improve the prevention, evaluation, management, and rehabilitation of catastrophic injuries. [18] NCCSIR captures catastrophic injuries and medical conditions several ways including searches of publicly available media reports, direct reports from sport and medical organizations and individuals including school and medical staff, and other researchers. Catastrophic injury events among high school and collegiate track and field athletes due to falls were captured through the NCCSIR database from 7/1/1982 to 6/30/2019. These cases were obtained through the means described above and were compiled by NCCSIR staff to obtain injury and athlete information. Detailed information about the events were obtained by contacting the athlete, their parents, coaches, or athletic trainers.

Additional catastrophic injuries from falls in track and field in the United States were gathered through ad hoc searches of public media reports through internet search engines, such as Google and databases such as EBSCO and PubMed, from 8/1/2020 to 10/30/2020. Search terms included *track+and+field+deaths*, *track+and+field+injuries,track+and+field+jumping+accidents*, *pole+vault+deaths,pole+vault+injuries,high+jump+deaths*, *high+jump+injuries*, *javelin+deaths*, and *javelin+injuries*. Additional events were obtained through *polevaultpower.com*, a forum board for pole vault enthusiasts where anyone could post serious pole vault injuries and deaths from 1997 to 2011. The cases identified from this forum board led to a secondary search of public media reports using the athlete's first and last name and *+pole+vault+injury* to obtain further detail about the injury event.

Catastrophic traumatic injuries from track and field captured using the above methods were reviewed to confirm that the injury was the result of a fall. Events that were possibly due to falls (e.g. mechanism of injury was contact with the ground) but did not have enough information to confirm a fall were excluded in this analysis. Catastrophic injuries to the head or brain, spine or spinal cord, and internal organ systems resulting from a direct contact with the ground or an object due to a fall were included in the analysis. Head or brain injuries included skull fractures, brain bleeds, and catastrophic traumatic brain injuries (TBIs). Spine injuries consisted of cervical, lumbar, and thoracic spine fractures and spinal cord injuries. Internal organ injuries included punctures, ruptures, lacerations, etc. of internal organ systems.

Injuries were reported by athlete characteristics (sex, sport level), event characteristics (event specialty, activity, month and academic year injured, type of session), and injury characteristics (body part injured, fall height, severity, mechanism). A fall from a different level was classified as any fall originating above ground level whereas a fall from the same level was any fall that originated on ground level and lead to a slip, trip, or fall. The injuries were stratified by sport level (high school and college) and by severity (death, permanent injuries, which were classified as any injury that resulted in a severe, lifelong disability, and temporary injuries, which were classified as any severe injury that did not result in a permanent functional disability). Descriptive statistical analyses were performed with SPSS Statistics 26. Fisher's exact tests were used to determine differences between injury and athlete demographics by sport level and severity. The level of significance was set at < 0.05. Data are presented as numbers and percentages (%).

Case details of 12 catastrophic injuries from falls were examined to determine Haddon's countermeasures. These 12 cases were selected because of their similar mechanism of injury and because there was an adequate level of detail for the proposed countermeasures analyses. Within these 12 cases, they were categorized by event specialty, sport level (high school vs. college), severity, and type of session and player activity.

RESULTS

From 1982 to 2019, NCCSIR captured a total of 61 catastrophic injuries in track and field from falls among high school and collegiate athletes. Athlete characteristics, event characteristics, and injury characteristics were compared by sport level (Table 1) and severity (Table 2). The majority of catastrophic fall-related injuries were from height (89%) during competition (53%) or practice (46%) at the high school level (72%). Overall, there were more male (93%) than female athletes who sustained catastrophic injuries from falls, but this difference was not statistically significant by sport level (p=0.308) (Table 1). The event specialty that comprised the most catastrophic injures from falls was pole vault (85%) followed by javelin throw (8%) and high jump (5%). In general, multiple variables did not vary by sport level (p>0.05), which included the activity being performed, the type of session, the body part injured, the severity of injury, the mechanism, and the fall height. The month that the injuries occurred was different by sport level (p=0.005). Most college athletes were injured from January to March (26%) while most high school athletes were injured from April to June (49%).

In terms of severity, all fatalities and permanent injuries were due to pole vault while all high jump and javelin throw catastrophic injuries resulted in temporary injuries (Table 2). More pole vaulters were fatally injured compared to high jumpers and javelin throwers (p=0.001). The activity that most athletes were doing at the time of injury was the action of pole vaulting which did vary by severity (p=0.012). There was one fatality that was not due to the action of pole vaulting when a pole vault athlete was performing a strength drill on a rope and fell. Fatalities were most often the result of head or brain injuries (21/61), while spine injuries resulted in either permanent (2/61)

and temporary injuries (3/61), and internal organ injuries resulted in temporary injuries (7/61) (p=0.000). Contact with the ground injury mechanism was more often associated with death and permanent injury, while contact with an object injury mechanism was more often associated with temporary injuries (p=0.001). The severity of the injury did not vary by sex, sport level, injury month, type of session, or fall height (p>0.05).

The number of annual catastrophic fall-related injuries from the 1982 academic year to the 2019 academic year are presented stratified by sport level (Figure 1) and severity (Figure 2). The number of fall-related catastrophic injuries ranged from 0-1 annually. Overall, the number of fall-related catastrophic injuries for high school track and field athletes appeared to decrease between 1982 to 2019, whereas the number for collegiate athletes remained consistent (Figure 1). The severity of catastrophic fall-related injuries varied from 1982 to 2019. The number of fatalities and permanent injuries appeared to decrease over the period while the number of temporary injuries appeared to increase (Figure 2).

Details from the 12 catastrophic injuries from falls and their Haddon injury prevention countermeasures are presented in Table 3. These cases included 7 high school athletes and 5 college athletes. Out of the 12 events selected, 10 were falls from a different level (83%) while 2 were from falls from the same level (17%). The falls from different levels occurred during pole vault (90%) and high jump (10%) events. Both falls from the same level were during javelin. Most of the injuries occurred at practice (58%) while the others took place at competitions (42%).

Seven athletes were injured while pole vaulting when they missed or did not land on the mat properly and struck their heads on the ground surrounding the landing pit. Two of these athletes were fatally injured. Another pole vault athlete was fatally injured from falling while performing a rope drill and hit his head on the ground despite having mats under the rope and two spotters. Two javelin athletes tripped on the ground and were impaled with the tail end of their javelin. A high jump athlete was injured falling from a height, missing the mat, and striking his head on the ground beside the landing area.

The most prominent countermeasures that appeared applicable throughout all of the cases were Haddon's countermeasures 9 (Begin to counter damage early from the hazard) and 10 (Stabilize, repair, and rehabilitate the object of damage). For the purpose of these injuries, countermeasure 9 suggests early recognition and implementation of an emergency action plan (EAP), onsite access to an athletic trainer, and rapid activation of EMS. Countermeasure 10 recommends providing definitive medical care. Countermeasure 8 (Separate the hazard from what is supposed to be protected by a physical barrier) was applied to 11 injury cases and suggest wearing personal protective equipment like helmets and safety glasses to reduce injuries. Countermeasure 6 (Separate the hazard from that which is to be protected by a physical barrier) was assigned to 10 of the injury cases to modify a part of the landing zone such as additional padding on the ground surrounding the landing zone, decreasing the size of the plant box, ensuring that mats are in good condition and properly attached, and to utilize a soft cover for the back end of the javelin. Countermeasure 7 (Modify relevant basic qualities of the hazard) was applied to 2 of the injury cases to dull the front and alter the back end of the javelin to be rounded or flat. Countermeasure 5 (Separate the hazard from that which is to be protected by time and space) was applied to 1 injury case to limit the number of steps or distance to pole vault.

Table 4 shows the Haddon matrix for pole vaulting which focused on the hazard of falling from a height related to the injury sequence. For pre-event injury prevention, teaching proper technique is highlighted as a way for the athlete to reduce the risk of injury for themselves. Other pre-event injury prevention strategies noted were maintaining and inspecting both poles and landing mats for damage and general condition. The other pre-event injury prevention strategy was to emphasize a culture of safety for both coaches and athletes. During the injury event, athletes should be taught how to land properly, such as on their backs and shoulders and to not let go of the pole until absolutely certain they are going to land on the mat. Other methods listed during the injury event are reducing gaps between the landing mats, ensuring mats are properly attached,

ensuring that a coach is present to monitor and correct the athlete's technique, and an athletic trainer is present and ready to treat any injuries. For post-event injury prevention strategies, both athletes and coaches should be taught when to get assistance and activate the EAP. Ensuring that the athletic trainer is present and educating coaches on how to provide appropriate emergency care before emergency personnel arrive to take over. Other post-event injury prevention strategies include catching the poles to avoid damage from striking the ground and placing the runway and pit in an area that is visible and easily accessible to athletic trainers and EMS. Table 5 shows the 10 countermeasures applied to pole vault, high jump, and javelin throw. Not all of the 10 countermeasures applied to the 3 field events such as countermeasure 3 for all events, countermeasures 4 and 5 for javelin throw, and countermeasure 7 for pole vault and high jump. Countermeasures 1, 8, 9, and 10 had the same application for all 3 events while countermeasures 2, 4, 5, and 6 had very similar applications to pole vault and high jump. Countermeasures 2 and 6 were used in javelin throw and had different applications to high jump and pole vault.

Table 1. Athlete, Event, and Injury Characteristics by Sport Level.

	College (n = 17)		High School (n = 44)		Total (n = 61)	
	n	Column %	n	Column %	n	Column %
Sex (chi-square = 1.043, p = 0.308)						
Male	15	88%	42	96%	57	93%
Female	2	12%	2	5%	4	7%
Injury Month (chi-square = 12.974, p = 0.005)						
January – March	7	41%	9	21%	16	26%
April – June	4	24%	26	59%	30	49%
July – September	3	18%	9	21%	12	20%
October – December	3	18%	0	0%	3	5%
Event Specialty (chi-square = 3.926, p = 0.439)						
Pole Vault	15	88%	37	84%	52	85%
Jumper	0	0%	3	7%	3	5%
Thrower	1	6%	4	9%	5	8%
Other	1	6%	0	0%	1	2%
Activity (chi-square = 6.512, p = 0.101)						
Pole Vaulting	13	77%	37	84%	50	82%
Jumping – High Jump	0	0%	3	7%	3	5%
Throwing – Javelin	0	0%	2	5%	2	3%
Other	4	24%	2	5%	6	10%
Type of Session (chi-square = 2.704, p = 0.387)						
Competition	9	53%	23	52%	32	53%
Practice	7	41%	21	48%	28	46%
Strength Session	1	6%	0	0%	1	2%
Body Part Injured (chi-square = 1.021, p = 0.662)						
Brain/Head	14	82%	35	80%	49	80%
Spine	2	12%	3	7%	5	8%
Internal Organs	1	6%	6	14%	7	12%
Injury Severity (chi-square = 0.268, p = 0.878)						
Permanent Injury	5	29%	12	27%	17	28%
Temporary Injury	7	41%	16	36%	23	38%
Fatal	5	29%	16	36%	21	34%
Mechanism (chi-square = 0.002, p = 1.000)						
Contact with Object	2	12%	5	11%	7	11%
Contact with Ground	15	88%	39	89%	57	89%
Fall Height (chi-square = 0.884, p = 0.386)						
Fall from a Height	14	82%	40	91%	54	89%
Fall from Same Level	3	18%	4	9%	7	11%

Figure 1. The Number of Catastrophic Injuries by Academic Year and Sport Level

[a] 1987 rule change: front buns (front pads that extended between the standards and around the box) were mandated
[b] 1995 rule change: athletes' weight must be at or below pole's rating, (recommendation) all non-soft surfaces adjacent to pit be padded
[c] 2003 rule change: mandated an increase in pit size to 19'8 x 16'5
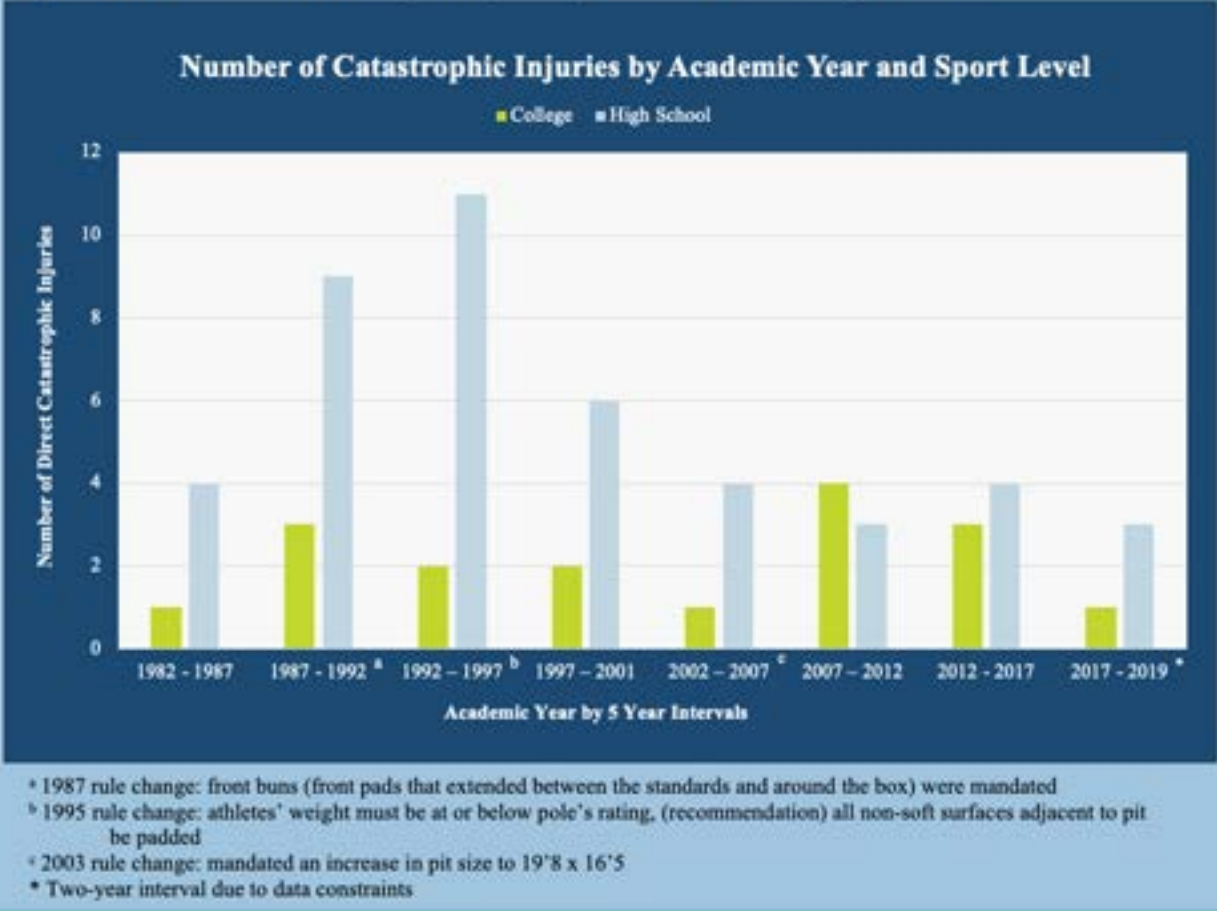[*] Two-year interval due to data constraints

Table 2. Athlete, Event, and Injury Characteristics by Severity.

	Fatality (n = 22)		Permanent Injury (n = 18)		Temporary Injury (n = 24)		Total (n = 61)	
	n	Column %	n	Column %	n	Column %	n	Column %
Sex (chi-square = 2.398, p = 0.371)								
Male	21	100%	15	88%	21	91%	57	93%
Female	0	0%	2	12%	2	9%	4	7%
Sport Level (chi-square = 0.268, p = 0.878)								
College	5	24%	5	29%	7	30%	17	28%
High School	16	76%	12	72%	16	70%	44	72%
Injury Month (chi-square = 6.641, p = 0.329)								
January - March	8	38%	5	29%	3	11%	16	26%
April – June	7	33%	10	59%	13	57%	30	49%
July – September	5	24%	2	12%	5	22%	12	20%
October - December	1	5%	0	0%	2	9%	3	5%
Event Specialty (chi-square = 17.443, p = 0.001)								
Pole Vault	21	100%	17	100%	14	61%	52	85%
Jumper	0	0%	0	0%	3	13%	3	5%
Thrower	0	0%	0	0%	5	22%	5	8%
Other	0	0%	0	0%	1	4%	1	2%
Activity (chi-square = 13.889, p = 0.012)								
Pole Vaulting	21	100%	15	88%	14	61%	50	82%
Jumping – High Jump	0	0%	0	0%	3	13%	3	5%
Throwing – Javelin	0	0%	0	0%	2	9%	2	3%
Other	0	0%	2	12%	4	17%	6	10%
Type of Session (chi-square = 4.561, p = 0.303)								
Competition	10	48%	12	71%	10	44%	32	53%
Practice	11	52%	5	29%	12	52%	28	46%
Strength Session	0	0%	0	0%	1	4%	1	2%
Body Part Injured (chi-square = 16.976, p = 0.000)								
Brain/Head	21	100%	15	88%	13	57%	49	80%
Spine	0	0%	2	12%	3	13%	5	8%
Internal Organs	0	0%	0	0%	7	30%	7	12%
Mechanism (chi-square = 13.064, p = 0.001)								
Contact with Object	0	0%	0	0%	7	30%	7	11%
Contact with Ground	21	100%	17	100%	16	70%	54	89%
Fall Height (chi-square = 5.109, p = 0.072)								
Fall from a Height	21	100%	15	88%	18	78%	54	89%
Fall from Same Level	0	0%	2	12%	5	22%	7	11%

Figure 2. The Number of Catastrophic Injuries by Academic Year and Severity.

[a] 1987 rule change: front buns (front pads that extended between the standards and around the box) were mandated
[b] 1995 rule change: athletes' weight must be at or below pole's rating, (recommendation) all non-soft surfaces adjacent to pit be padded
[c] 2003 rule change: mandated an increase in pit size to 19'8 x 16'5
* Two-year interval due to data constraints
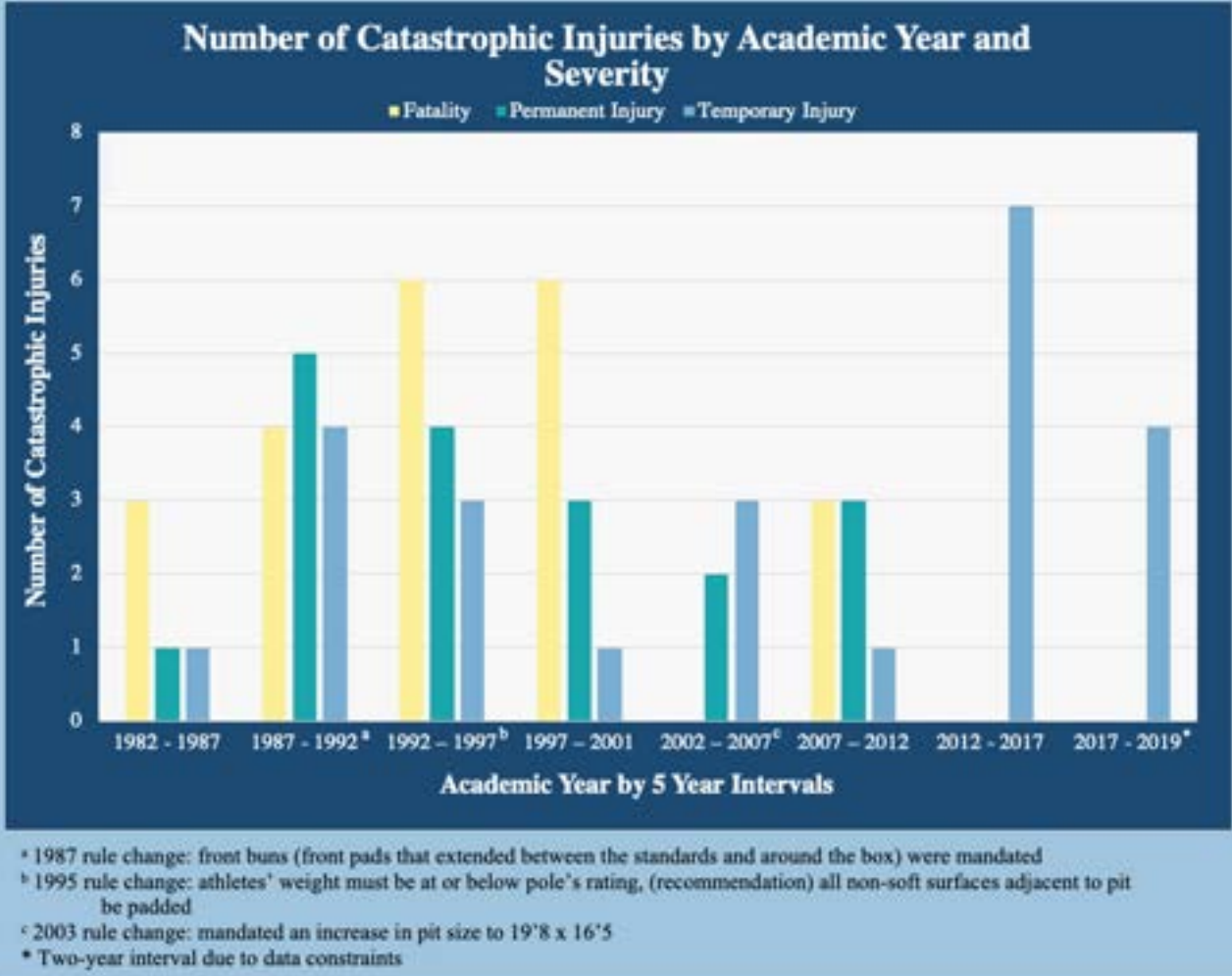
Table 3. Details from the 12 cases of catastrophic injuries and their corresponding Haddon countermeasure.

Event Specialty	Sport Level	Severity	Session, Activity	Narrative	Countermeasures
Pole Vault	High School	Temporary injury, Full recovery	Meet, Pole vaulting	A male senior high school athlete was injured during a meet when he was vaulting and his pole snapped. It is unknown if the pole was within regulation at the time. He fell into his pole which impaled and struck his orbital bone. He was transported by EMS (emergency medical serviced) via ambulance to the hospital. He underwent a five-hour surgery and 40 stitches to repair his eye. A full recovery was expected.	5. Separate the hazard from that which is to be protected by time and space (limit the number of steps or distance from the pit allowed to be vaulted from) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)
Pole Vault	High School	Temporary injury, Full recovery	Meet, Pole vaulting	A male sophomore high school athlete was injured during a meet when he was pole vaulting. His pole stalled as he reached the peak of his arch and his head struck the concrete and fractured his skull. He underwent treatment in the hospital's ICU. A full recovery was expected.	8. Make what is to be protected more resistant to the damage from the hazard (use protective gear such as helmets) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)
Pole Vault	High School	Temporary injury, Full recovery	Practice, Pole vaulting	A female sophomore high school athlete was injured during an indoor practice when she was pole vaulting. Her pole stalled to the side she fell sideways toward the side mats. As she fell, she spotted her landing and released her pole; however, she misjudged her landing and landed halfway on the mat and her head struck the floor. She was diagnosed at the hospital with an epidural hematoma and flown to different hospital where doctors drained the clot. A full recovery was expected.	6. Separate the hazard from that which is to be protected by a physical barrier (add additional pads in front of standards) 8. Make what is to be protected more resistant to the damage from the hazard (use protective gear such as helmets) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)

Table 3. (continued) Details from the 12 cases of catastrophic injuries and their corresponding Haddon countermeasure.

Pole Vault	High School	Temporary injury, Full recovery	Practice, Pole vaulting	A male senior high school athlete aged 18 was injured during practice when he was pole vaulting. During his landing, he partially missed the mat and struck his head on the concrete. He was losing consciousness and having seizures immediately after falling. EMS transported him via ambulance to the hospital. He underwent surgery to repair a compression skull fracture where a portion of his brain was severed and removed. Later, he suffered from a transient-ischemic attack and was taken back to the hospital. A full recovery was expected.	6. Separate the hazard from that which is to be protected by a physical barrier (provide additional pads in front of standards) 8. Make what is to be protected more resistant to the damage from the hazard (use protective gear such as helmets) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)
Javelin	High School	Temporary injury, Full recovery	Meet, Retrieving javelin	A male senior high school athlete aged 18 was injured during a pre-meet warmup when he tripped and fell into the back end of his javelin when he went to retrieve it. The javelin pierced his right eye-socket and was removed on-scene before EMS arrived. EMS transported him via helicopter to the hospital. A full recovery was expected.	6. Separate the hazard from that which is to be protected by a physical barrier (create soft cover for back of javelin) 7. Modify relevant basic qualities of the hazard (Dull the ends of the javelin with the back end blunted) 8. Make what is to be protected more resistant to damage from the hazard (wear eye protection) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)
Pole Vault	College	Death	Practice, Rope drill	A male sophomore college athlete aged 19 was injured during a practice where he was performing strength drills on a rope. He fell and hit his head on the concrete while the rest of his body landed on the mat. There were two spotters and a mat under the rope. He was pronounced brain dead at the hospital two days later.	6. Separate the hazard from which is to be protected by a physical barrier (use additional mats in all fall areas) 8. Make what is to be protected more resistant to damage from the hazard (wear protective gear such as helmets) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)

Table 3. (continued) Details from the 12 cases of catastrophic injuries and their corresponding Haddon countermeasure.

Pole Vault	College	Temporary injury, Full recovery	Practice, Pole vaulting	A male college athlete aged 22 was injured during a practice where he was pole vaulting. During his vault, he released his pole prematurely and fell from 15 feet into the metal box sustaining a severed spinal cord. It is unknown if a box collar was used during this practice. EMS transported him via ambulance to the hospital. He was later transported to a different hospital via helicopter. He underwent a 4 hour long spinal surgery to stabilize his spine. He remains paralyzed from the navel down and a recovery was expected.	6. Separate the hazard from which is to be protected by a physical barrier (decrease the size of the planting box) 8. Make what is to be protected more resistant to damage from the hazard (wear protective gear such as helmets) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)
Pole Vault	College	Death	Meet, Pole vaulting	A male college athlete was injured during a meet where he was attempting to clear 11 feet while pole vaulting. During his landing, he landed to the right of the center and the mat collapsed below him and separated from the mat beside it causing him to strike the ground. He was pronounced deceased at the hospital 7 days later.	6. Separate the hazard from that which is to be protected by a physical barrier (ensure that mats are properly inspected and properly attached) 8. Make what is to be protected more resistant to damage from the hazard (wear protective gear such as helmets) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)
Pole Vault	College	Temporary injury, Full recovery	Practice, Pole vaulting	A male college athlete aged 19 was injured during while pole vaulting with some new poles. During his jump, his pole flexed and propelled him out rather than up. He was thrown to the back edge of the mat and struck his head on the turf below. He was immediately transported to the hospital via helicopter where he underwent surgery to remove part of his skull to allow for the swelling in his brain. A full recovery was expected.	6. Separate the hazard from that which is to be protected by a physical barrier (use additional mats surrounding the back and sides of the landing zone) 8. Make what is to be protected more resistant to damage from the hazard (wear protective gear such as helmets) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)

Table 3. (continued) Details from the 12 cases of catastrophic injuries and their corresponding Haddon countermeasure.

Pole Vault	College	Death	Meet, Pole vaulting	A male sophomore college athlete aged 19 was injured during a meet where he was attempting to clear 15 feet and 7 inches. During his jump, his pole stalled while he was inverted and he let go of his pole and landed in the metal box. It is unknown if a box collar was used during this meet. EMS transported him via ambulance to the hospital. He was pronounced deceased a few hours later.	6. Separate the hazard from that which is to be protected by a physical barrier (decrease the size of planting box) 8. Make what is to be protected more resistant to damage from the hazard (wear protective gear such as helmets) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)
High Jump	High School	Temporary injury, Full recovery	Practice, High jumping	A male high school athlete was injured during a practice where he was attempting to clear 5 feet and 8 inches. During his jump, he ran past his mark and jumped closer to the far side standard. This resulted in him missing the mat and striking his head on the ground. The school's athletic trainer was called who called 911. EMS transported him via ambulance to the hospital. He was later flown to a different hospital where he was treated for a subdural bleed and underwent three surgeries to relieve the pressure in his brain. A full recovery was expected.	6. Separate the hazard from that which is to be protected by a physical barrier (use additional mats around the sides and back of landing zone) 8. Make what is to be protected more resistant to damage from the hazard (wear protective gear such as helmets) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)
Javelin	High School	Temporary injury, Full recovery	Practice, Javelin	A male sophomore high school athlete aged 19 was injured at a practice while he was attempting to stop a rolling discus with his javelin. While stopping the discus, he tripped and fell onto it penetrating through his abdomen and out his back. He pulled the javelin out of his abdomen on scene. It went to the hospital where he underwent surgery to repair his stomach, pancreas, and left kidney. A full recovery was expected.	6. Separate the hazard from that which is to be protected by a physical barrier (create soft cover for back of javelin) 7. Modify relevant basic qualities of the hazard (Dull the ends of the javelin with the back end blunted) 8. Make what is to be protected more resistant to damage from the hazard (wear protective gear such as eye protection) 9. Begin to counter damage from the hazard (early recognition and implementation of emergency action plan, have onsite access to an athletic trainer, and rapid activation to EMS) 10. Stabilize, repair, and rehabilitate the object of damage (provide advanced definitive care)

Table 4. Haddon matrix applied to pole vault for overall prevention methods.

	Host (Athletes)	Agent (Energy)	Physical Environment (Overall Design)	Social Environment
Pre-Event	Teach athletes proper pole-vaulting technique before being allowed to vault (eg. how to ensure enough momentum to avoid stalling).	Use tacky spray, athletic tape, and keep poles dry to ensure grip on poles and reduce slipping during inversion; check pole for cracks and damage.	Ensure minimum standard of mat widths are met and are in good condition and properly attached before allowing use and provide additional mats on hard areas (eg. concrete, turf, runway).	Cultivate social norms that only trained athletes should use equipment and only in the presence of a coach. Also have coaches emphasize safety and safe practices when teaching.
Event	Teach athletes how to land to minimize and avoid injury (eg. Not to let go of pole unless they have spotted over mat and land on back and shoulders rather than feet).	Teach athletes to push pole away from them to avoid landing on pole during fall. Reduce area of gaps between mats and standards, box, and other mats to avoid areas where athletes could fall and not be easily extricated.	Ensure that mats are present, properly connected and in good condition and provide adequate fall protection. Consider additional padding in surrounding landing area.	Ensure that a coach and athletic trainer are present to monitor athlete safety.
Post-Event	Teach coaches and teammates when to get assistance (eg. how to activate the emergency action plan, call for the athletic trainer, and activate EMS). Ensure an athletic trainer is present and ready to provide care.	Ensure that poles are caught after vault to avoid poles hitting ground to avoid damage to the pole.	Place pit and runway in an open area that is easily accessible and visible to athletic trainers and EMS.	Ensure that coaches and athletic trainers are equipped with the training to provide adequate first aid to injured athlete before emergency personnel arrives.

Table 5. Haddon's Ten Countermeasures for Pole Vault, Javelin, and High Jump.

Countermeasures	Pole Vault	Javelin	High Jump
1. Prevent the creation of the hazard	Eliminate event.	Eliminate event.	Eliminate event.
2. Reduce the amount of hazard brought into being	Limit height allowed to vault.	Dull point on end of javelin.	Limit height allowed to jump.
3. Prevent the release of the hazard	N/A	N/A	N/A
4. Modify the rate of release of the hazard from its source	Limit height of poles used by athlete age. Use taller pads to decrease distance of fall.	N/A	Limit height allowed to jump by athlete age. Use taller pads to decrease distance of fall.
5. Separate the hazard from that which is to be protected by time and space	Limit number of steps (minimize distance from planting box) that athletes can vault from.	N/A	Limit number of steps (minimize distance from mat) that athletes can jump from.
6. Separate the hazard from that which is to be protected by a physical barrier	Decrease the size of planting box. Create wider pads that extend further in front and side of box.	Use a soft cap for back end of javelin.	Create pads that extend around and behind the standards.
7. Modify relevant basic qualities of the hazard	N/A	Dull ends of javelin with the back end blunted.	N/A
8. Make what is to be protected more resistant to damage from the hazard	Use protective gear (helmets, eye protection).	Use protective gear (helmets, eye protection).	Use protective gear (helmets, eye protection).
9. Begin to counter damage from the hazard	Early recognition and implementation of an EAP, have onsite access to an athletic trainer, rapid activation of EMS.	Early recognition and implementation of an EAP, have onsite access to an athletic trainer, rapid activation of EMS.	Early recognition and implementation of an EAP, have onsite access to an athletic trainer, rapid activation of EMS.
10. Stabilize, repair, and rehabilitate the object of damage	Provide advanced, definitive care.	Provide advanced, definitive care.	Provide advanced, definitive care.

DISCUSSION

In this study, pole vault had the highest number of catastrophic fall-related injuries regardless of the level of expertise. Similarly, regardless of the level, head/brain injuries were the most common body part injured followed by internal organ injuries in high school and spinal injuries in college. There were more high school athletes injured in contrast with collegiate athletes. However, there was a higher total number of high school athletes, both male and female, compared to collegiate athletes. Over a 37 year period from 1982 to 2019, the NFHS reports that there were 20,519,788 male and 16,733,866 female high school track and field athletes [1] and the NCAA reports that there were 1,506,690 male and 1,317,991 female athletes. [19] There were no statistics on the participation number of male athletes versus female athletes by event specialty in either high school or college, and since the majority of catastrophic injuries were pole vault athletes, there could be many more male pole vaulters than female pole vaulters which could explain the difference in the number of injuries. This disproportion in injuries could also be due to males being more likely to be more competitive and take greater risks than females in sports. [20] There was no statistical difference between the sex of injured athlete and sport level. There was also not a statistical difference among the sport level and the demographics of athlete, event, or injury, except for the month that injuries occur. This is likely because both high school and collegiate track and field athletes traditionally compete in the spring months; however, since more college athletes have access to indoor facilities than high school athletes, college athletes most likely practice more frequently and consistently during the colder months of January to March.

Pole vault athletes also comprised the most severe injuries from falls including fatalities and permanent injuries compared with high jump and javelin throw athletes. Since pole vaulters are launched to much higher heights than high jumpers and javelin throwers, the possibility of a pole vaulter sustaining a more severe injury from a fall than a high jumper or javelin thrower is likely due to the height difference of the fall sustained. This is consistent with more fatal and permanently disabling head/brain injuries from falls. It is more likely that an athlete falling from a great height would be more likely to sustain an injury to head/brain which could lead to more severe outcomes. Throwing and jumping were associated with temporary injuries. This is likely due to the height of falls that occur in javelin throw and high jump. High jump is performed at lower heights than pole vault which decreases the risk of injury from falls comparatively. Since javelin throw is performed from the ground, the likelihood of a fall from a height is low. A fall from the same level does not inherently have the same risks that a fall from a height has because of the increase of force that occurs as the height increases [21]. However, a fall from any level onto an object could result in a catastrophic injury because of the high level of concentrated force associated with a small surface area (i.e. a javelin). One reason a fall could lead to a javelin thrower sustaining a catastrophic injury of less severity than a pole vaulter is that the javelin thrower would most likely be falling from the same level onto an object which would present a more variable mortality rate than falling from a height. This occurs because the mortality rate of a penetrating trauma is limited to the structures penetrated whereas a high fall can lead to many potentially fatal injuries like the head/skull trauma, cardiac rupture, aorta, heart, lungs, spleen and liver, and spine. [22]

There have been three major rule changes in the event of pole vaulting to reduce the risks catastrophic injury and death. The first was in 1987 when front buns (large pads extending from the base of the standards to around the plant box) were mandated. [23] In 1995, a rule stated that an athlete's weight must be at or below the manufacturer's pole rating. [24] Lastly in 2003, the minimum pit size was increased to 19'8" by 16'5.' [25] Overall, the trend of catastrophic injuries for high school track and field athletes appeared to decrease between 1982 to 2019, whereas the number for collegiate athletes remained consistent (Figure 1). In comparison with the trend of catastrophic injuries from pole vault that Boden et al. [9] collected from 1982 to 2011, this trend remains consistent between catastrophic injuries from falls and pole vault. Fatalities and permanent injuries appeared to decrease over the years. These changes in trend over the years for severity and sport level may indicate that rule changes improved the safety of pole vaulting. In contrast, the number of temporary injuries appeared to increase. However, this could be due to the rule changes improving the safety of the falls and decreasing the severity of injuries but not necessarily the overall number of catastrophic injuries. This could also be due to the improvement of media and technology that led to an increase of media coverage of less severe injuries compared to only high profile fatalities.

There are a number of ways to reduce injury by modifying different interactions during the injury event. For the pole vault and high jump athletes who hit their heads falling from a height, the same countermeasure of wearing personal protective equipment, like helmets, was applied to all cases. Previous literature indicates this is a controversial prevention method because there is a lack of research supporting the effectiveness

for jumping sports [6] and possible athlete resistance to wearing them. [26] However, there are currently 6 states that require high school pole vaulters to wear helmets [26] and there have been studies of helmet effectiveness in sports like skiing and snowboarding that show their ability to reduce head, neck, and cervical spine injuries. [27] Though high jump is performed from a much lower height, helmets should also be considered as an intervention because there is still a possibility of a head injury. The addition of helmets to the uniform would be easier to implement at the high school level when the jumpers are learning their event rather than at the collegiate level where those athletes are more experienced and not used to practicing with headgear. As a cost-effective and potential life-saving intervention, further studies should continue to assess whether they might be able to reduce injuries specifically in jumping events.

Protective equipment should not be limited to only jumping events. Both cases of javelin-related injuries in this study highlight the necessity to protect against the apparatus itself. Two countermeasures that could minimize the risks of impalement are wearing safety glasses and creating a soft cap for the back of the javelin itself. These interventions could possibly decrease the risk of injury if an athlete falls onto their apparatus. The surface condition and type of footwear that the athletes were wearing during the event in these cases were unknown, but these elements could have been a factor in tripping and falling. Ensuring appropriate footwear and adequately maintained throwing surfaces should be considered for injury prevention as it is thought to reduce slipping and sticking on the ground. [7]

Another countermeasure noted was the use of mats in both pole vault and high jump. Since many of the injuries occurred from high jump and pole vault athletes missing the mat completely or partially, it seems likely that increasing the minimum requirements of the mat area would help decrease injury from missing the mat. This is another source of contention for both events because of the high cost of the addition or change of mats. [5] A possible alternative to this countermeasure would be to add soft pads adjacent to all sides of the landing mat, which would be lower in cost and therefore more affordable for schools, but still provide some protection for falls.

The plant box is another dangerous area where pole vault athletes have landed. Interventions were adopted in the 2015-2016 school year when the National Collegiate Athletic Association (NCAA) made it mandatory to include a box collar as a part of the pole vault regulations in order to lessen the impact of a fall into the plant box. [28] A study from 2017 on injuries from landing in the plant box indicates that the severity of some falls have been reduced by the addition of the current box collar; however, due to the small sample size of this study, additional research is needed to further establish the effectiveness of this intervention. [29] An alternative or addition to improving the safety regarding the plant box is to decrease the size of the plant box itself. This would decrease the area of risk, and in turn, decrease the chance of falling into it. Using this idea combined with the box collar could reduce the severity of injury caused by falls on this hard surface.

After an injury occurs, the countermeasures are the same for each of the 3 field events and are applicable in all 12 of the cases. This highlights the importance of minimizing injury post-event. For these field events, availability of athletic trainers should be made a priority during practice and competitions. However, rapid access to definitive medical care is the most necessary intervention after a catastrophic injury has occurred. [30] If an athletic trainer is not available, coaches and athletes should be aware of the Emergency Action Plan (EAP), know how to implement it, and activate EMS. Basic training in first aid, CPR, and Automated External Defibrillator (AED) use should also be a consideration for coaches because it could help stabilize the athlete prior to emergency personnel's arrival and avoid endangering the athlete more by providing well-intentioned, but harmful medical care. Another consideration for schools is to make facilities easy to locate and access for emergency personnel in order to expedite extrication and definitive medical care.

Arguably the most important and effective method of injury minimization and prevention occurs before the athlete even touches the field since a core belief of injury control is that injuries are not unpreventable accidents but occur from interactions of uncontrolled

energy transfer among a host, an agent, and environment. [14] Most injuries and risks can be minimized with proper instruction. Boden et al [5] also cites the importance of quality instruction from coaches as a factor in injuries. Due to the unique nature of pole vaulting, specialized instruction for coaches could decrease the overall risk of injuries. This should be a two-fold endeavor. First, to adequately and effectively teach technique, landing safely, and pole management, and secondly, to cultivate an environment where safety is the priority. By creating an environment where safety is not only the expectation for the athlete, but also the coach, it could help coaches impart the importance of safety to their athletes.

The following limitations should be noted. Catastrophic injuries are rare and the descriptive analyses for the 61 falls in this study was limited by small sample sizes. NCCSIR strives to capture all catastrophic injuries. However, reliance on publicly available media reports results in incomplete capture of catastrophic injuries, particularly the less severe (temporary injury) events which may not reach the mainstream media. The 12 cases highlighted for countermeasure analysis were not intended to be representative of all high school and collegiate falls in track and field. The data collected from internet search engines are dependent on media reports. These media reports contain limited information and do not always include use of protective gear, condition of equipment such as landing mats, poles, or javelins, expertise (how many years athlete/coach had performed the activity), or environmental factors which could all have been factors leading to injury. Future studies are needed to address these factors to formulate additional targeted intervention strategies.

CONCLUSION

Falls in track and field can lead to severe injuries, including fatalities. The greatest number and most severe of these falls were due to pole vaulting. One of the greatest risks a fall opens to an athlete is an injury to the head/brain. Falls, especially from a height, leave the head in a vulnerable position which could lead to catastrophic injuries. There are many different prevention measures that can be taken to reduce injuries. Any number of these seemingly small strategies could have the potential to reduce the severity of injuries for athletes. Since there is a large population of high school and collegiate athletes competing in track and field, these interventions become more important to design and implement. These fall-related catastrophic injuries highlight the importance of continued surveillance to improve our understanding of the incidence and injury patterns to develop interventions to reduce the impact these injuries have on athletes.

ACKNOWLEDGEMENTS

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About the Author

Christina Vu is a graduating senior at the University of North Carolina at Chapel Hill majoring in Exercise and Sport Science and studio art. Beginning in her sophomore year, she became a research assistant in the Cognitive Affective Science Lab where she collected data to investigate the role of emotion knowledge and stress. Later, she joined the National Center for Catastrophic Sport Injury Research as a research assistant collecting catastrophic sport injury cases from media reports. In her senior year, she began an independent research project about injury prevention methods for falls in track and field which was inspired by her own experience as a pole vault athlete throughout high school. After graduation, Christina plans to continue working in Orange County as an emergency medical technician, creating art, and hanging out with her cats, Puppy and Sulley.

The Association Between Type 2 Diabetes Mellitus and Mild Cognitive Impairment Through Visualizations Provided by Diffusion Weighted Imaging and Diffusion Tensor Imaging

by Shivam Gandhi

Mild cognitive impairment (MCI) is often a comorbidity in type 2 diabetic (T2DM) patients. Using preexisting scans on white matter (WM) brain regions from the Alzheimer's Disease Neuroimaging Initiative (ADNI), we examine the structural brain differences in T2DM patients with and without MCI, not limited to a specific brain region. Diffusion weighted imaging (DWI) and diffusion tensor imaging (DTI) was used to visualize and measure the patients' ailments. DWI measures the anisotropic diffusion of water along various white matter tracts in the brain, allowing for clear visualization of deep brain areas. DTI will quantify the imaging done by DWI into specific scalar values, including fractional anisotropy (FA), which provides data on how free diffusion occurs based on direction. Prior research indicates that T2DM patients with MCI exhibit lower FA values, indicating more restricted osmosis in brain regions such as the corpus callosum, the cingulum, and the hypothalamus. The preexisting FA data of T2DM patients with and without MCI were analyzed in JASP using the two-way ANOVA feature. Three significant values showed up, indicating a possible correlation between diabetes and specific tracts in the brain. These tracts corresponded to two brain regions: the corpus callosum and the cingulum. However, after performing false discovery rate correction, these statistically significant values failed to pass correction for multiple comparison. This means that there are still some type I errors (rejection of a true null hypothesis) affecting the statistically significant values calculated in JASP. This led us to the conclusion that although some uncorrected significant values indicate a possible connection between diabetes and structural changes associated with MCI, the lack of corrected significant values indicates that MCI and CN individuals do not show differing FA values in the brain as a function of T2DM prevalence.

Keywords: mild cognitive impairment, type 2 diabetes mellitus, diffusion weighted imaging, diffusion tensor imaging, fractional anisotropy

INTRODUCTION

Cases of dementia have been increasing in prevalence over the last century. With the increase in life expectancy through medical advancement, the number of common chronic cases in older people is becoming more observed, the most common being Alzheimer's disease (AD). 26.6 million AD cases were reported worldwide in 2006, and by 2050 the prevalence is expected to quadruple, with 1 in 85 people living with the disease. The associated cost of taking care of dementia patients will also increase with the number of cases (Rocca et al., 2011).

This increase in AD incidence can be counteracted by early screenings that catch the disease before its official onset. This can be done by monitoring transition states, the most common being mild cognitive impairment (MCI). MCI represents an early phase of AD, and recent research has taken great interest in defining early treatment modalities that represent a transition state between cognitively normal functioning and dementia (Angelucci et al. 2020). Sharing many of the symptoms with AD, MCI can provide researchers with a way to detect and treat cognitive decline in its earliest stage.

Both AD and MCI are often exhibited as comorbidities with

type 2 diabetes mellitus (T2DM) in patients. T2DM targets the entire body, including the brain, placing several diabetic patients at risk for developing MCI and AD. Neural dysfunctions in T2DM patients result from underlying mechanisms such as metabolic changes and are regulated by age-related endocrine changes (Jayaraman et al., 2014). More specifically, T2DM results in axon degradation and injury to myelinated fibers in brain regions associated with MCI and AD onset, including the cingulum and the corpus callosum (Figure 1). Both are associated with connecting the brain and allowing communication to occur between different brain regions; the cingulum plays a critical role in limbic system communication, where the hippocampus is located, while the corpus callosum connects the two hemispheres of the brain (Xiong et al. 2016).
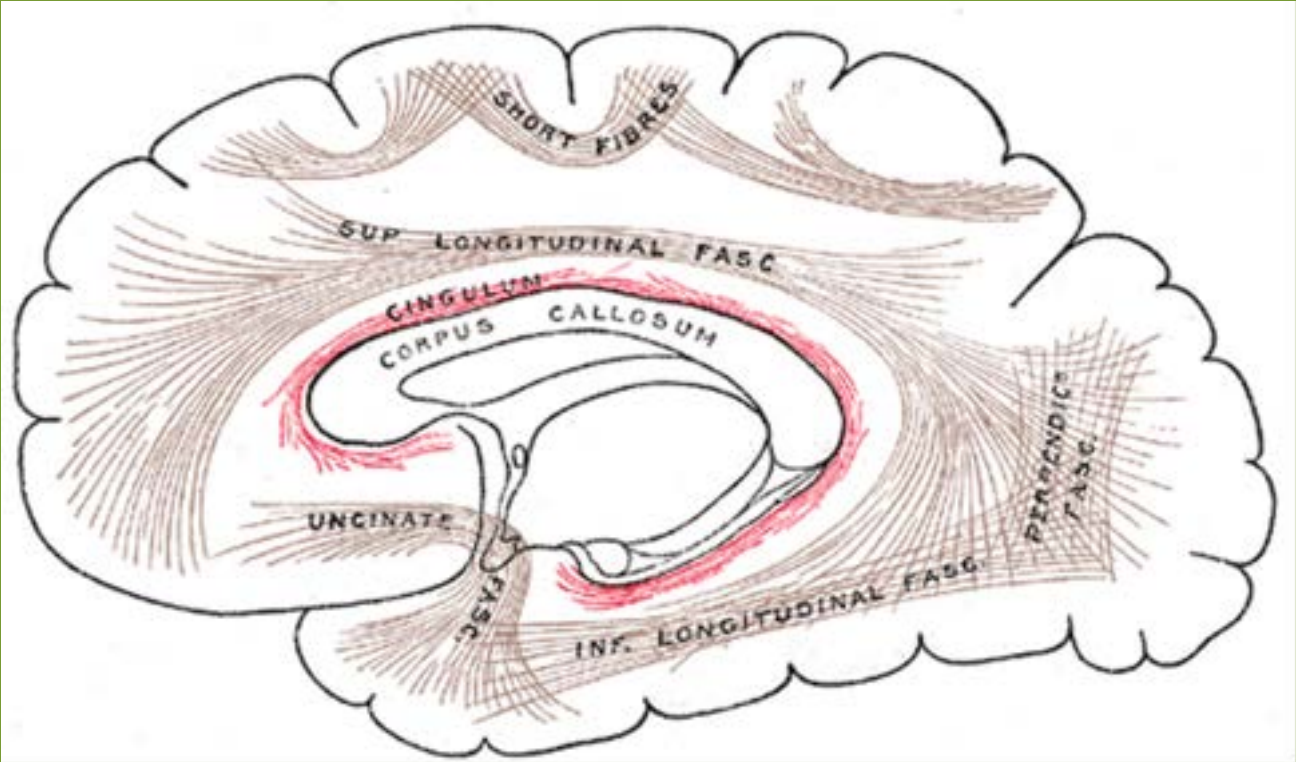
Figure 1. Image of the Corpus Callosum and Cingulum in the brain (Rocca et al 2011).

Structural analysis of these brain regions can be done through MRI. However, a novel imaging method that measures the anisotropic diffusion of water in brain regions by applying a magnetic field serves a better purpose. This imaging method is Diffusion Weighted Imaging (DWI) and based on the varying levels of osmosis in different brain regions. Models can be constructed using Diffusion Tensor Imaging (DTI) and come in various forms, providing more information and better visualization of deep brain regions than MRI (O'Donnell et al. 2011).

We hypothesized that structural differences in T2DM patients with and without MCI are not limited to a specific deep brain region. We also wanted to see if DWI/DTI effectively provided structural information about deep brain regions that would support our hypothesis. Finally, we observed the relationship between T2DM and various parameters such as age, education, and MMSE scores. Several previous students provided findings that were inconsistent to a specific brain region, so we set up our experiment to be more exploratory to understand the large-scale relationship between T2DM and MCI in terms of deep brain regions.
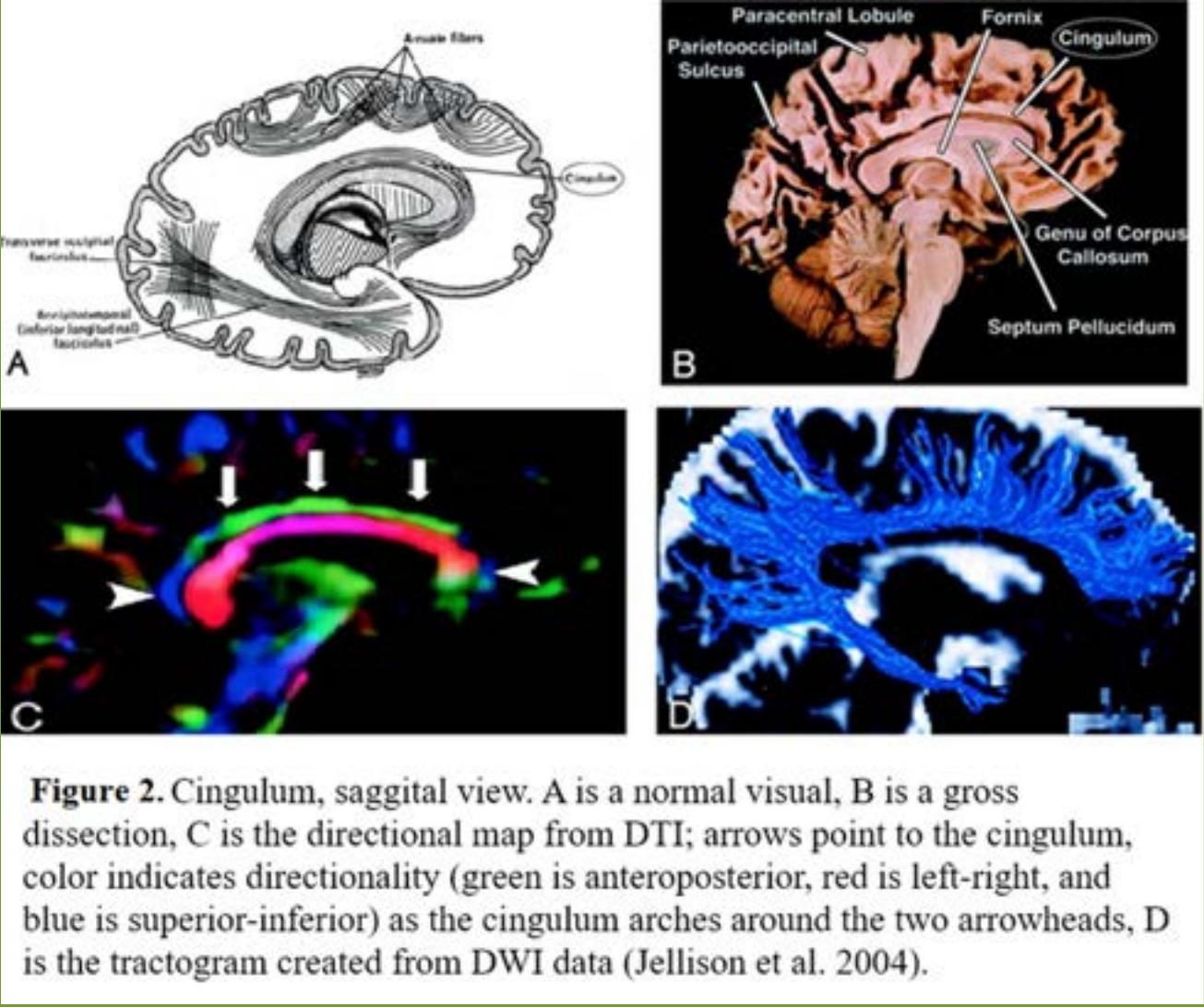
Figure 2. Cingulum, saggital view. A is a normal visual, B is a gross dissection, C is the directional map from DTI; arrows point to the cingulum, color indicates directionality (green is anteroposterior, red is left-right, and blue is superior-inferior) as the cingulum arches around the two arrowheads, D is the tractogram created from DWI data (Jellison et al. 2004).

METHODS

Our first specific aim was to observe the efficiency of DWI/DTI in measuring anisotropic diffusion of water in white matter (WM) brain regions and in quantifying the diffusion into scalar values, respectively. Based on the orientation of the axons, diffusion of water can be slower if orthogonal to the axon or faster if parallel (O'Donnell et al., 2011). This provides a range of diffusion values corresponding to different tissue orientations, which are then quantified into tensor values. There are four major metrics used in DTI: fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD). Each metric focuses on a specific aspect of the diffusion values collected from DWI. MD will average all scalars; RD averages the scalar values that represent diffusion in the minor directions; AD only quantifies the scalar value that represents diffusion in the major direction, and FA quantifies the fraction of diffusion anisotropic (Do 2015). FA was selected as our parameter because it provides the most information about white matter regions associated with MCI (Figure 3).
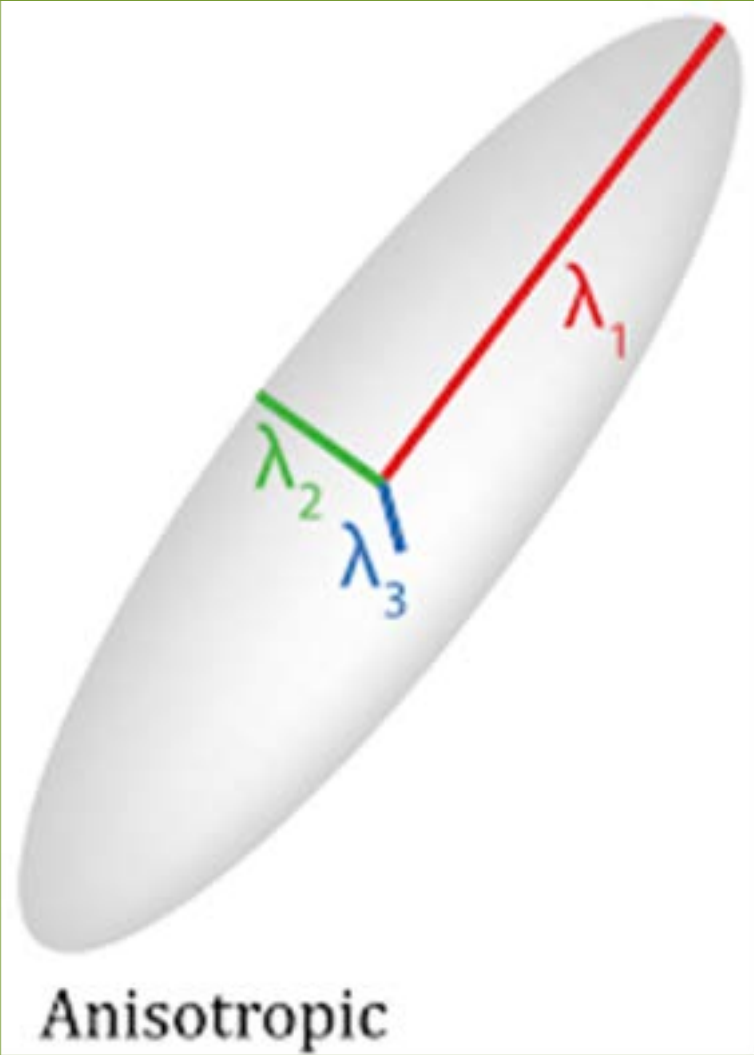
Anisotropic

Figure 3. Representation of anisotropic diffusion. FA is calculated by taking the relative difference between the largest vector ($\lambda 1$) and the other vectors ($\lambda 2$ and $\lambda 3$) (Do 2015).

Our second specific aim was to use FA values of T2DM patients with and without MCI to determine any significant structural differences in brain regions. Previous studies indicated that lower FA values were observed in WM regions in patients with T2DM and even lower FA values in patients with MCI and T2DM (Xiong et al., 2016). Preexisting data was used in this study; the Alzheimer's Disease Neuroimaging Initiative (ADNI) provided us with all DTI metrics and diabetic data. This data was then sorted to remove all metrics except FA and any duplicate patients and patients with AD for a total of 186 patients. This data was then analyzed using two-way ANOVA to see if there were any possible interactions between FA in specific brain regions and diagnosis, including cognitively normal (CN) patients and MCI patients, with diabetes as a covariable. Finally, for each relevant p-value, we created a figure and learned more about the specific brain region.

Our third specific aim was to examine the relationship between various parameters such as age, education, and mini-mental state examination (MMSE) scores, and diabetes. MMSE scores are used to measure cognitive decline, and we expected a correlation to exist between that and diagnosis. We gathered this data from ADNI and matched it with the 186 patients used in the previous study. We then performed the same type of analysis on JASP and noted any significant p values; however, we did not create any figures.

RESULTS

Table 1 shows the results of the statistical tests performed; 3 specific tracts that showed statistically significant correlations between FA values and diabetes. These tracts correspond to two different brain regions: BCC_L and SUMBCC correspond to the bilateral corpus callosum, and CGC_L corresponds to the Cingulum. A figure was created for each tract with a statistically significant value showing the FA value for the tract vs. diagnosis (CN or MCI), with diabetes as a covariable.

Table 1. ANOVA between FA tracts and Diabetes. Bolded values correspond to the statistically significant p values between FA tracts and diabetes.

Tract	Diabetes F	Diabetes p	Partial η²	Tract	Diabetes F	Diabetes p	Partial η²
CST_L	0.573	0.45	0.003	SLF_L	0.291	0.590	0.002
CST_R	0.0007567	0.978	0.000004158	SLF_R	0.114	0.736	0.0006264
ICP_L	0.362	0.548	0.002	SFO_L	0.140	0.709	0.0007679
ICP_R	0.431	0.512	0.002	SFO_R	3.064	0.082	0.017
ML_L	0.417	0.519	0.002	IFO_L	0.467	0.495	0.003
ML_R	0.489	0.485	0.003	IFO_R	0.699	0.404	0.004
SCP_L	1.372	0.243	0.007	SS_L	1.835	0.177	0.010
SCP_R	0.136	0.712	0.0007491	SS_R	2.199	0.140	0.012
CP_L	2.112	0.148	0.011	EC_L	2.104	0.149	0.011
CP_R	1.238	0.267	0.007	EC_R	1.609	0.208	0.009
ALIC_L	0.063	0.802	0.0003473	UNC_L	1.817	0.179	0.010
ALIC_R	0.347	0.557	0.002	UNC_R	1.109	0.294	0.006
PLIC_L	0.042	0.837	0.0002333	FX_L	0.443	0.506	0.002
PLIC_R	0.005	0.945	0.00002618	FX_R	2.264	0.134	0.012
PTR_L	0.0008300	0.977	0.000004560	GCC_L	0.935	0.335	0.005
PTR_R	0.481	0.489	0.003	GCC_R	0.340	0.561	0.002
ACR_L	0.146	0.702	0.0008036	**BCC_L**	**5.187**	**0.024**	**0.028**
ACR_R	1.735	0.189	0.009	BCC_R	3.303	0.071	0.018
SCR_L	0.700	0.404	0.004	SCC_L	3.271	0.072	0.018
SCR_R	1.361	0.245	0.007	SCC_R	3.365	0.068	0.018
PCR_L	0.305	0.582	0.002	RLIC_L	2.150	0.144	0.012
PCR_R	1.119	0.292	0.006	RLIC_R	1.555	0.214	0.008
CGC_L	**4.322**	**0.039**	**0.023**	TAP_L	1.128	0.290	0.006
CGC_R	3.064	0.082	0.017	TAP_R	3.730	0.055	0.020
CGH_L	1.860	0.174	0.010	SUMGCC	0.603	0.439	0.003
CGH_R	0.525	0.470	0.003	**SUMBCC**	**4.183**	**0.042**	**0.022**
FX_ST_L	2.544	0.122	0.014	SUMSCC	3.384	0.067	0.018
FX_ST_R	2.198	0.140	0.012	SUMCC	3.317	0.070	0.003
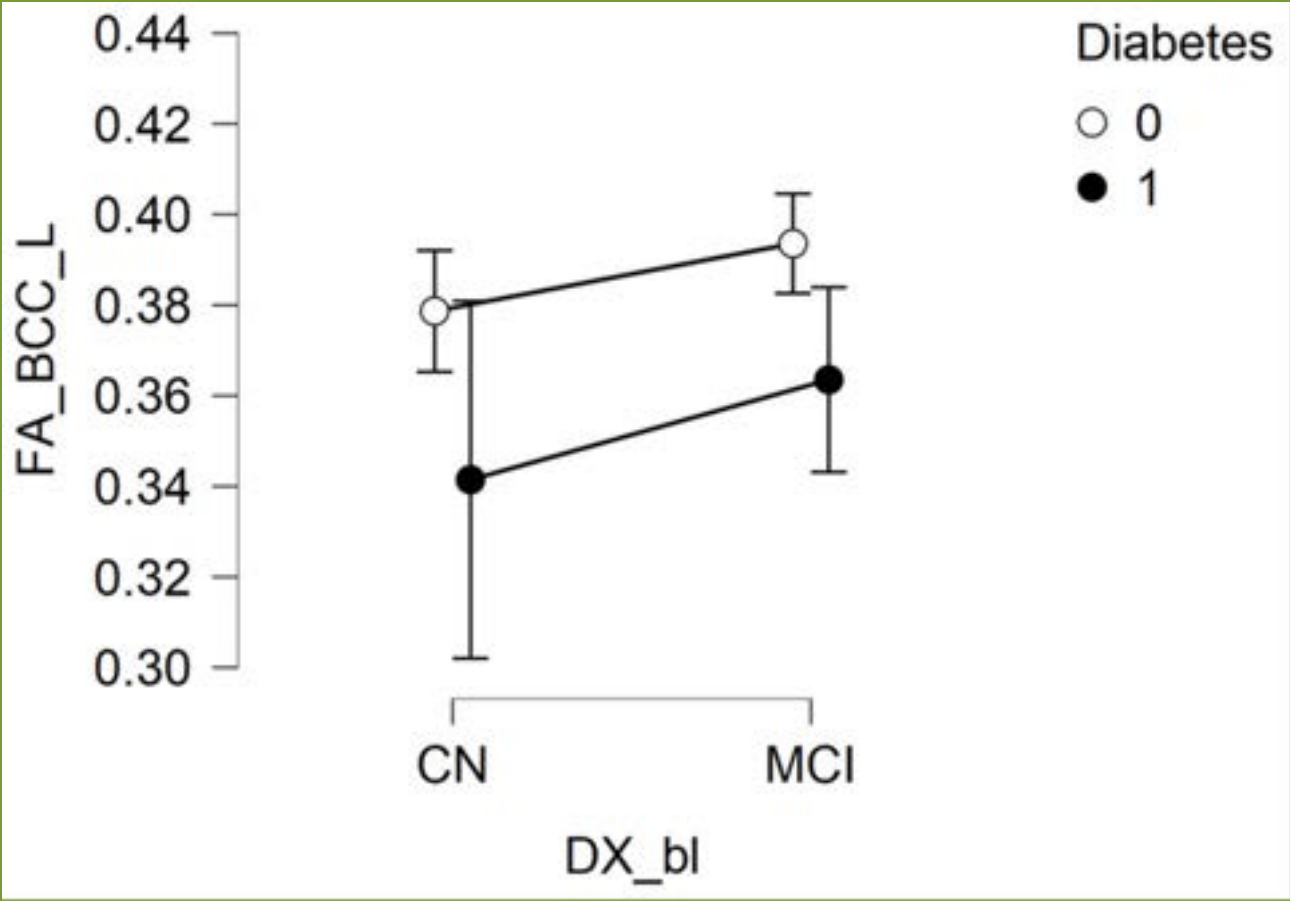
Figure 4. FA values in the Left Bilateral Corpus Callosum vs. Diagnosis. Higher FA values were observed in T2DM patients with MCI. A value of 1 corresponds to having T2DM, while a value of 0 corresponds to not having T2DM. A significant p value is a p value that is less than 0.05.
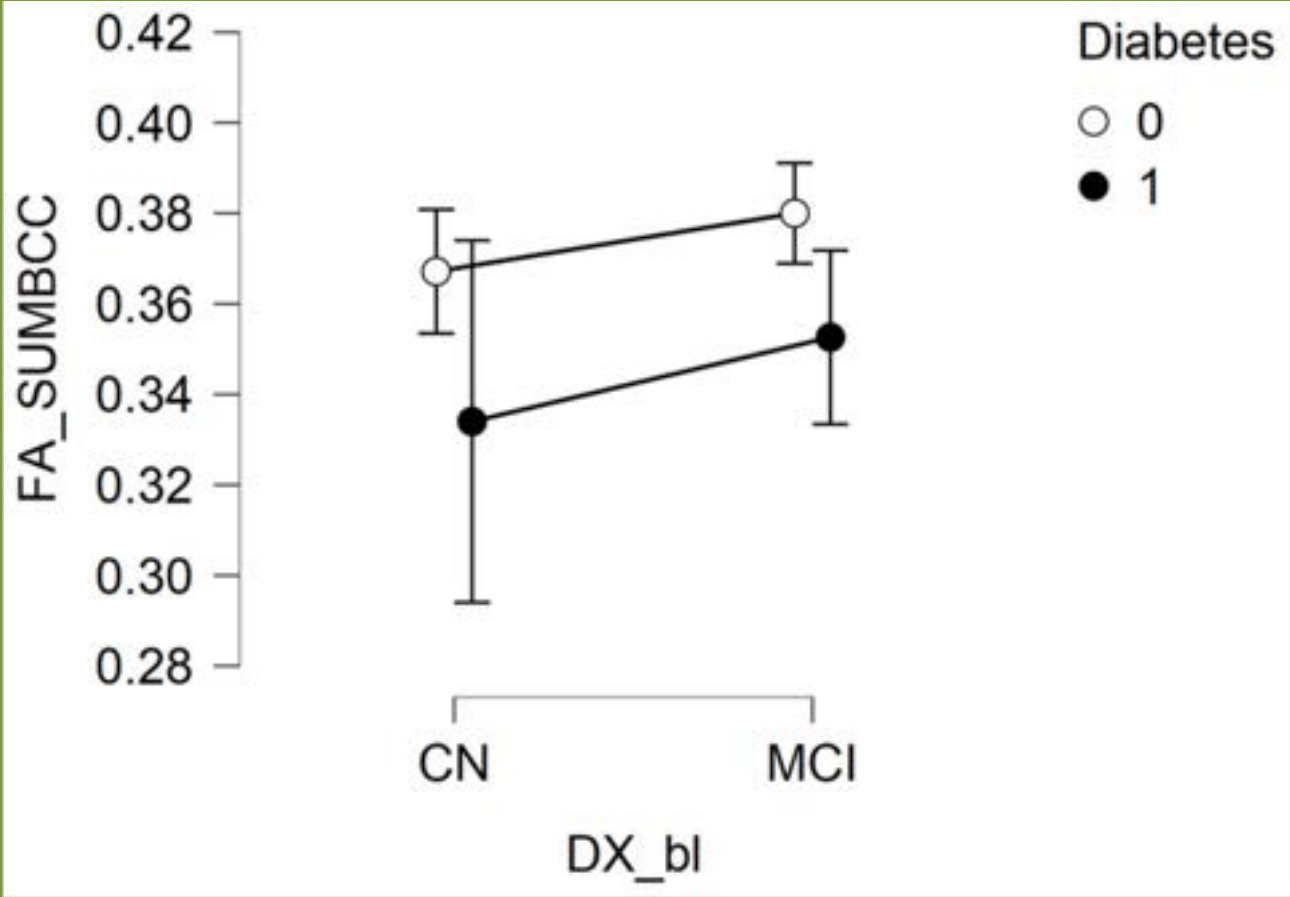
Figure 5. FA values in the entire Bilateral Corpus Callosum vs. Diagnosis. Higher FA values were observed in T2DM patients with MCI. A value of 1 corresponds to having T2DM, while a value of 0 corresponds to not having T2DM. A significant p value is a p value that is less than 0.05.
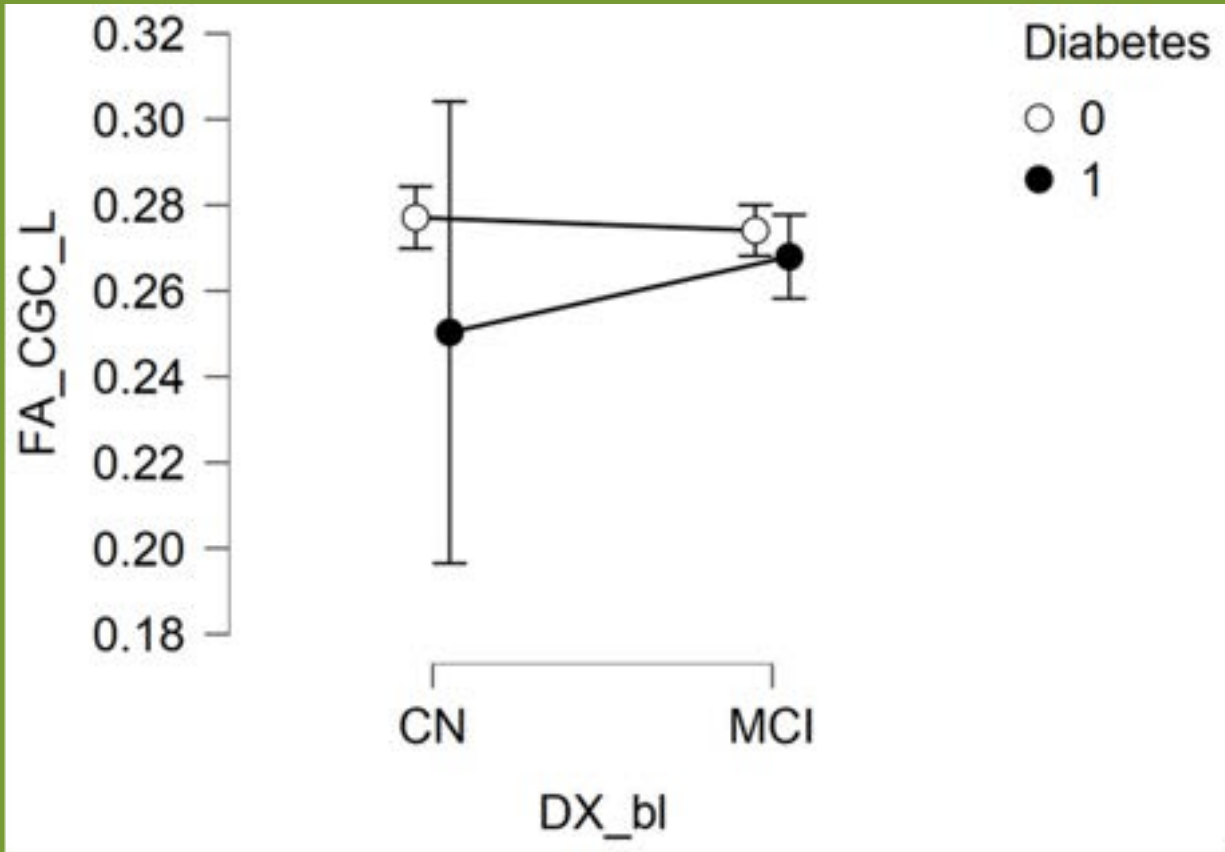
Figure 6. FA values in the Cingulum at the Cingulate Gyrus vs. Diagnosis. Higher FA values were observed in T2DM patients with MCI. A value of 1 corresponds to having T2DM, while a value of 0 corresponds to not having T2DM. A significant p value is a p value that is less than 0.05.

Table 2 presents the results of the tests performed between various parameters and diabetes. Each row represents a specific parameter, and each column corresponds to a factor. Both age and education showed no significant results when compared to diabetes. MMSE scores, which are used to display cognitive decline, showed one significant result with diagnosis.

Table 2. ANOVA between Demographics and Diabetes, Diagnosis, and the interaction between the two. Bold values indicate statistically significant p-values between the demographic and the factor.

	Diabetes F	Diabetes p	Partial η²	DX F	DX p	Partial η²	Interaction F	Interaction P	Partial η²
Age	0.941	0.333	0.005	0.042	0.838	0.0002305	0.345	0.558	0.002
MMSE	0.005	0.941	0.00002986	4.619	**0.033**	0.025	0.081	0.776	0.00004450
Education	0.453	0.502	0.002	0.246	0.621	0.001	0.110	0.741	0.0006014

DISCUSSION

DWI/DTI creates accurate models for various WM brain regions. Figure 2 from another study shows a visual comparison between the actual and the DTI-created cingulum; it successfully shows the general position of the brain structure and its directionality. Figure 3C shows the cingulum undergoing a twist going from left to right, which is indicated by the different colors and arching along with another brain structure, which is indicated by arrowheads. The tractogram in figure 3D displayed specific WM tracts connected to the cingulum and were created using DTI parameters (Jellison et al. 2004).

The statistically significant values shown in figures 4-6 indicate a relationship between the white matter tracts and diabetes. However, we ran a false discovery rate (FDR) analysis, which tests the rate of type I errors when testing the null hypothesis through multiple comparisons, and the p values failed to pass. This indicates that several false positives affect our data (Korthauer et al., 2019). However, this does not reject the relationship between T2DM and diagnosis; this just indicates that our data set is flawed by errors.

DWI/DTI is a powerful imaging technique that has great application in imaging WM regions that are difficult to visualize typically. Scalar values and 3D models provide information about the structure of various brain regions and the variation of FA in different WM regions. These are good indicators of MCI onset, especially in regions such as the corpus callosum and the cingulum, where statistically significant relationships exist between the FA values in WM tracts located in those regions and diagnosis. T2DM represents a covariable that affects FA values in these regions; T2DM patients exhibit lower than average FA values, but T2DM patients with MCI generally show even lower FA values. When comparing demographics such as age, education, and MMSE scores with diagnosis, no significant results were found. We conclude that because of a lack of corrected p-values, MCI and CN individuals do not show differing FA values in the brain due to T2DM prevalence.

FDR analysis showed that the statistically significant values

are affected by type I errors, which can be attributed to the sample population used in this study. Our study was also limited by the size of the sample population and relied on data processed by others. However, the conclusion of our study and the limitations present do not indicate that there is no relationship between T2DM and MCI. The next step would be to perform the study again on a larger sample population for which the researchers collected the data. This would minimize the number of errors affecting the results. Also, DWI/DTI should be extended to other studies that utilize WM tissue imaging; they are excellent at visualizing deep WM tissue in the brain and serve many roles in brain studies that look at the functionality of key regions. That way, patients with an ailment that presents as comorbid with cognitive decline can get the proper treatment for their condition.

ACKNOWLEDGEMENTS

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About the Author

Shivam Gandhi became involved in this research project through my cousin; he was doing his radiology fellowship at UNC hospitals, and got him involved in research at the department of radiology. At first, he worked with Dr. Dayan by helping him with data analysis, but in Fall 2020 he was able to perform guided research under his supervision. They looked at the changes in Fractional Anisotropy (FA) in the brains of patients with Type 2 Diabetes (T2DM) to find a correlation between Type 2 Diabetes and Mild Cognitive Impairment (MCI). They observed changes in FA in the Cingulum and Corpus Callosum, indicating that DWI/DTI is effective in measuring FA values in the brain and that there is some correlation between T2DM and MCI.

Impact of Winter Ocean Warming and Reduced Heterotrophy on the Physiological Response of the Temperate Coral *Oculina arbuscula*

by Tyler Christian

Increasing sea surface temperatures from anthropogenic climate change cause significant stress to marine organisms. A plethora of studies have examined the response of corals to thermal stress under controlled laboratory conditions, which often led to bleaching or mortality of the corals. However, these studies have mainly focused on investigating the response of tropical corals to elevated summer seawater temperatures, leaving a gap in our understanding of how temperate corals are responding to elevated winter temperatures. In this study, we investigated the physiological response of the temperate coral, *Oculina arbuscula*, to end-of-century winter ocean warming and reduced food availability for heterotrophy predicted under climate change. Colonies of *O. arbuscula* were reared for 60 days in two temperature treatments: present-day winter average seawater temperature and elevated winter ocean temperature for predicted end-of-the-century conditions in the northwestern mid-Atlantic region. The corals were also exposed to two feeding treatments of freshly hatched *Artemia* sp. nauplii (low and normal) to examine the effects of heterotrophy on the net calcification rate of the corals. The results of this experiment showed that elevated winter temperatures caused increased calcification rates compared to present-day winter conditions. We also found that heterotrophy has little effect on growth rates for *O. arbuscula*. These findings could have important implications for our understanding of how corals might respond to future climate change effects.

Keywords: temperate coral, winter warming, heterotrophy, calcification, Oculina arbuscula

INTRODUCTION

Coral reef ecosystems are an essential resource for humans and marine organisms alike. The complex reef structures created by corals provide habitat and food sources for marine and terrestrial organisms, protection along the coast from waves and storms, economic benefits from tourism and fishing (Bindoff et al., 2019; Brander et al., 2007), and biodiversity within the oceans (Hoegh-Guldberg et al., 2007). Coral reefs create their calcium carbonate skeletal structures through the uptake of calcium and carbonate ions in the water column via calcification (Drenkard et al., 2013; Rodolfo-Metalpa et al., 2010). Over the past several decades, rates of coral calcification have declined due to anthropogenically-induced global stressors. Anthropogenic carbon dioxide (CO_2) absorbed by the oceans is causing a decrease in ocean pH and carbonate saturation states (Drenkard et al., 2013; Ries et al., 2010; Rodolfo-Metalpa et al., 2010; Smith et al., 2016). These effects, together with the formation of carbonic acid from CO_2 equilibrating with seawater, is a process known as ocean acidification (Drenkard et al., 2013; Edmunds, 2011; Smith et al., 2016). Additionally, sea surface temperatures (SST) in the 20th Century were on average 0.74 ℃ higher than previous centuries, and temperatures are predicted to continue to increase by up to 4 ℃ by the end of the century (Abram et al., 2019; Hansen et al., 2006; Hoegh-Guldberg et al., 2007; Lord & Whitlach, 2015). Sea surface Temperature is increasing due to atmospheric CO_2 amplifying the greenhouse effect (Hoegh-Guldberg et al., 2007).

Temperature directly impacts coral calcification rates, and influences both seawater pH and carbonate saturation state, further affecting calcification (Courtney et al., 2017). As a result, coral calcification is expected to continue decreasing due to increased SST and ocean acidification as global climate change persists (Aichelman et al., 2016; Drenkard et al., 2013; Rodolfo-Metalpa et al., 2010).

Corals are mixotrophic organisms, meaning they utilize both autotrophic and heterotrophic feeding to gain the nutrients and energy necessary for growth. Autotrophy provides carbon to the coral host through photosynthesis carried out by its algal endosymbionts, Symbiodiniaceae, living within the coral tissue (LaJeunesse et al., 2018; Leal et al., 2014; Smith et al., 2016). Heterotrophy supplements organic carbon obtained from autotrophy, in addition to supplying nutrients, such as nitrogen and phosphorus, needed for tissue growth, symbiont regulation, and reproduction (Smith et al., 2016). Heterotrophy occurs through the capture of dissolved organic matter, particulate organic matter, and zooplankton from the surrounding water column (Aichelman et al., 2016; Leal et al., 2014; Smith et al., 2016). While both of these feeding mechanisms can occur in corals, both methods are not necessary for corals to meet their nutritional demands. In fact, autotrophy can provide up to 100% of a coral's daily metabolic requirements under optimal light

conditions (Aichelman et al., 2016; Leal et al., 2014). In particular, scleractinian corals, which are stony or hard corals, display a range of feeding behaviors with some species using primarily autotrophy and others using primarily heterotrophy (Miller, 1995). Corals commonly rely on heterotrophy as a food source more heavily during suboptimal conditions, such as reduced light availability; many temperate corals utilize heterotrophy in the winter for this very reason (Ferrier-Pagès et al., 2011). During periods of stress, such as those caused by elevated SST, corals bleach, a phenomenon in which they lose their symbionts and the ability to gain nutrients via autotrophy, thus losing a large portion of their food source (Smith et al., 2016). Bleaching can cause reduced coral health, growth, and reproduction, ultimately leading to coral mortality (Grottoli et al., 2006). Heterotrophy has been shown to increase in bleached corals to maintain metabolism and assist in recovery (Aichelman et al., 2016; Grottoli et al., 2006; Leal et al., 2014; Miller, 1995; Rodrigues & Grottoli, 2007). Several studies have shown that heterotrophy can actually reduce the effects of increasing SST and ocean acidification by minimizing calcification reductions and reducing harm or loss of symbionts (Aichelman et al., 2016; Edmunds, 2011; Grottoli et al., 2006). Therefore, heterotrophy could offer a possible method for corals to cope with added stress from climate change, but this effect has not been examined in many temperate coral species.

Oculina arbuscula is a temperate scleractinian coral found in the northwestern and mid-Atlantic Ocean (Aichelman et al., 2016; Leal et al., 2014; Miller, 1995; Ries et al., 2010). It is widespread along the eastern coast of the United States, and establishes a large portion of the benthic hardground shelf ecosystems (Ries et al., 2010), which support economically and biologically important fisheries for the Atlantic Ocean (Aichelman et al., 2016). It is a facultatively symbiotic coral, meaning it does not need symbionts to survive (Aichelman et al., 2016; Miller, 1995). Oculina arbuscula is adaptable and tolerates wide ranges of temperature, salinity, and light variations (Miller, 1995; Ries et al., 2010), indicating it will likely be able to survive the changing ocean conditions as a result of climate change. A few previous studies have investigated the impact of heterotrophy on temperate corals, including O. arbuscula, under thermal stress (Aichelman et al., 2016; Rodolfo-Metalpa et al., 2010), but none have examined the impact of heterotrophy and winter warming on coral physiological responses. Rather, these previous studies focused on the effect of heterotrophy and rising summer temperatures on O. arbuscula's physiological response. Currently, corals grow faster under summer seawater temperatures than winter temperatures (Miller, 1995), but with rising SST, winter temperatures may replace summer temperatures as the optimal growing environment for coral. Higher winter SST may provide better conditions for growth when thermal stress in the summer causes bleaching events and associated reduced calcification rates. Investigation of winter warming would, therefore, help us determine the impact of seasonal thermal stress, enabling us to better predict how temperate corals are likely to respond to end-of-century winter warming due to climate change.

Additionally, due to increased stratification reducing the supply of nutrients to the upper ocean, global marine primary production is predicted to decline under current climate change projections (Kwiatkowski et al., 2019). Under the business-as-usual Representative Concentration Pathway (RCP 8.5), phytoplankton biomass will decline by 6.1% and zooplankton biomass will decline by 13.6% over the 21st Century (Kwiatkowski et al., 2019). This means heterotrophic food sources available to corals will decrease. In addition, nutrient limitations will decrease phytoplankton nitrogen and phosphorus content relative to carbon levels (Kwiatkowski et al., 2019). This decrease will lead to trophic amplification as organisms relying on nutrition from phytoplankton and, thus, organisms relying on them, receive less food with lower nutrition. Examining the response of O. arbuscula under varying feeding levels is necessary to assess the influence of heterotrophy on coral adaptability. Such findings will help answer important management questions for temperate corals, especially for those that utilize heterotrophy more heavily than other species.

The aim of the current experiment was to investigate the effects of projected winter ocean warming and predicted declines in zooplankton abundance for heterotrophic feeding on the physiological response of the temperate coral, Oculina arbuscula. Since O. arbuscula is relatively adaptable to temperature and light changes (Miller, 1995), investigating this species allows us to understand how relatively adaptable temperate corals will respond to increasing SST.

MATERIALS AND METHODS

Coral Collection and Maintenance

Fifteen colonies of *Oculina arbuscula* were collected from Radio Island, North Carolina on October 10, 2018 at a 10 meter depth using a hammer and chisel. The colonies were transported to the Aquarium Research Center at the University of North Carolina at Chapel Hill. In the lab, the colonies were maintained in two 500 Liter recirculating holding tanks at 22°C, which was the average temperature at Radio Island at the time of collection. Water temperature in the holding tanks was gradually decreased by 1°C per week until they reached 11°C to mimic *in situ* winter seawater temperatures at the collection site. Seawater temperatures were based on data from the NOAA buoy (station BFTN7) most proximal to the collection site to obtain average weekly temperature records at this location for the past 10 years. The holding tanks were maintained at a salinity of 35 using deionized water and Instant Ocean Sea Salt, which was most similar in chemical composition to natural seawater when compared to other available commercial seawater mixes (Atkinson & Bingman, 1997). The corals were exposed to an irradiance of 150 μmol photons m-2 s-1, characteristic of low light habitats such as that of the collection site (D'angelo & Wiedenmann, 2012). Mesh sheets were placed on the tank lids for shading to replicate light conditions at the collection site depth. All colonies were fed equal amounts of freshly hatched *Artemia* sp. nauplii once a week (80 mL). Each holding tank had a 50% water change weekly.

Recovery and Acclimation

Each of the fifteen *O. arbuscula* colonies was sectioned into twelve comparatively-sized ramets to ensure that each genet was represented within each treatment level. The corals were sectioned using a diamond-embedded band saw. The ramets were affixed to sterile, prelabeled plastic petri dishes using cyanoacrylate. The ramets were allowed to recover for 30 days before pre-adjustment buoyant weights were measured. The coral ramets were then moved to their separate experimental tanks, with each genet's ramet randomly placed within their respective treatment tank to reduce bias against optimal flow rates and light conditions within each tank. Pre-acclimation buoyant weights were taken. Ramets were then allowed to acclimate gradually to temperatures and feeding quantities based on assigned treatment for 23 days. T0 (time zero) buoyant weights were then conducted at the start of the experiment.

Experimental Design

Twelve 38 Liter experimental tanks were divided into four identical experimental systems, with three tanks in each system. Six of the twelve tanks were assigned to the ambient temperature treatment (average *in situ* temperature at Radio Island) and the remaining six tanks were assigned an elevated temperature treatment (average *in situ* temperature plus 5°C). Within each temperature treatment, three of the six tanks were maintained at low feeding levels (~100 *Artemia* sp. nauplii per mL), while the other three tanks were maintained at ambient feeding levels (~500 *Artemia* sp. nauplii per mL). Therefore, three tanks were maintained at ambient feeding and ambient temperature, three at ambient feeding and elevated temperature, three at low feeding and ambient temperature, and three at low feeding and elevated temperature. One ramet from each colony was present in each of these twelve tanks so that each genet was represented in all treatments. The experiment was conducted for two months (January 25 through March 25) during most of the winter season in the Atlantic Ocean.

The Apex system was connected to a chiller (AquaEuroUSA Model: MC-1/13HP) for each treatment to maintain constant water temperature within the experimental tanks. The ambient

treatment was maintained at ~13°C, while the elevated treatment was maintained at ~18°C. Flow rates in the experimental tank systems were maintained at 291 GPH.

Each tank was illuminated with actinic and daylight bulbs (50-60 Hz). The lighting was on a 12-hour system with the beginning and end of the period only exposing the corals to actinic light to simulate sunrise and sunset. Corals were irradiated with 150 μmol photons m-2 s-1 with both the lights on and only 90 μmol photons m-2 s-1 when the actinic lights were on.

Each of the three 38 Liter tanks in a system was connected to the same 190 Liter sump to recirculate water through the tanks. Each sump had a protein skimmer (Eshopps) to remove organic material, which were cleaned daily. Corals were fed every day to mimic food availability within the water column. The corals received freshly hatched *Artemia* sp. nauplii at least 1 hour after the lights turned off for the day to simulate crepuscular feeding. Ambient feeding conditions were determined from zooplankton abundance averaged from multiple surf zone sites in southeastern North Carolina (8240 individuals per m³) (Stull et al., 2016). This value was used to calculate the quantity of *Artemia* sp. nauplii needed for ambient feeding within the experiment tanks, which was ~500 *Artemia* sp. nauplii per mL. Low feeding was one-fifth of this at ~100 *Artemia* sp. nauplii per mL. Ramets were periodically moved around in the tanks to minimize bias of small flow rate variation that might affect the quantity of food available to a specific ramet.

Experimental Tank Conditions

Salinity was maintained at 35, but evaporation often similarly increased salinity in all tanks before each water change. This increase was counteracted through intermittent additions of DI water in all systems until the next water change. Salinity was measured with a refractometer (Cole-Parmer Model: RSA-BR32T) daily. Water changes (33%) were performed twice a week to maintain salinity conditions and reduce excess nutrients. The saltwater mix was cooled to treatment levels using a chiller in order to avoid periods of warmer temperature conditions within the experimental tanks. Water temperature was monitored every day using a glass thermometer, while pH was monitored every other day so adjustments could be made accordingly. Plexiglass sheets, 3 mm thick, were used as lids on each tank to help minimize evaporation. Tank flow was maintained by pumps (Rio⁺ 2100) within each sump at a flow rate of 2630 LPH. Individual tanks each contained two powerhead pumps (Hydor USA) with flow rates of 240 GPH. Chillers had a flow rate of 291 GPH. Nitrate (NO_3^-) concentrations were tested weekly using the Aquarium Pharmaceuticals Nitrate Test Kit (API) to check for excess nutrients building up in the tanks. If build up occurred, a water change was performed.

Calcification Rates

Oculina arbuscula calcification rates were estimated using a Cole-Parmer bottom-loading balance, following the buoyant weight method (Spencer Davies, 1989). Coral ramets were buoyant-weighed post-recovery, pre-acclimation, at the start of the experiment, every 30 days during the experiment, and at the end of the experiment. Samples were wrapped in aluminum foil and frozen at -80°C at the conclusion of the experiment until lab protocols were initiated. Samples were then thawed for approximately 10 minutes and tissue was removed via airbrushing with seawater into a Ziploc bag. This tissue slurry was then transferred to 50 mL conical tubes and refrozen until needed later for lab protocols.

Dry weights of 45 coral skeletons were measured and plotted against the corresponding sample's final buoyant weight to determine a relationship between the two methods. The relationship was used to determine dry weights for the other coral samples and all buoyant weight measurements taken before and during the experiment.

RESULTS

Elevated Winter Temperature Increased Calcification Rates

While many studies have examined how corals respond to warmer summer seawater temperatures, it is unknown how they will respond to the warmer winter temperatures predicted with climate change. We found that calcification rates were significantly higher for *Oculina arbuscula* corals reared at elevated winter seawater temperature compared to corals reared at present-day winter seawater temperature. Additionally, calcification rates were higher for corals reared under low feeding conditions at both present-day winter seawater temperature and elevated end-of-century winter seawater temperature treatment conditions when compared with conspecifics reared under normal feeding conditions (Figure 1).
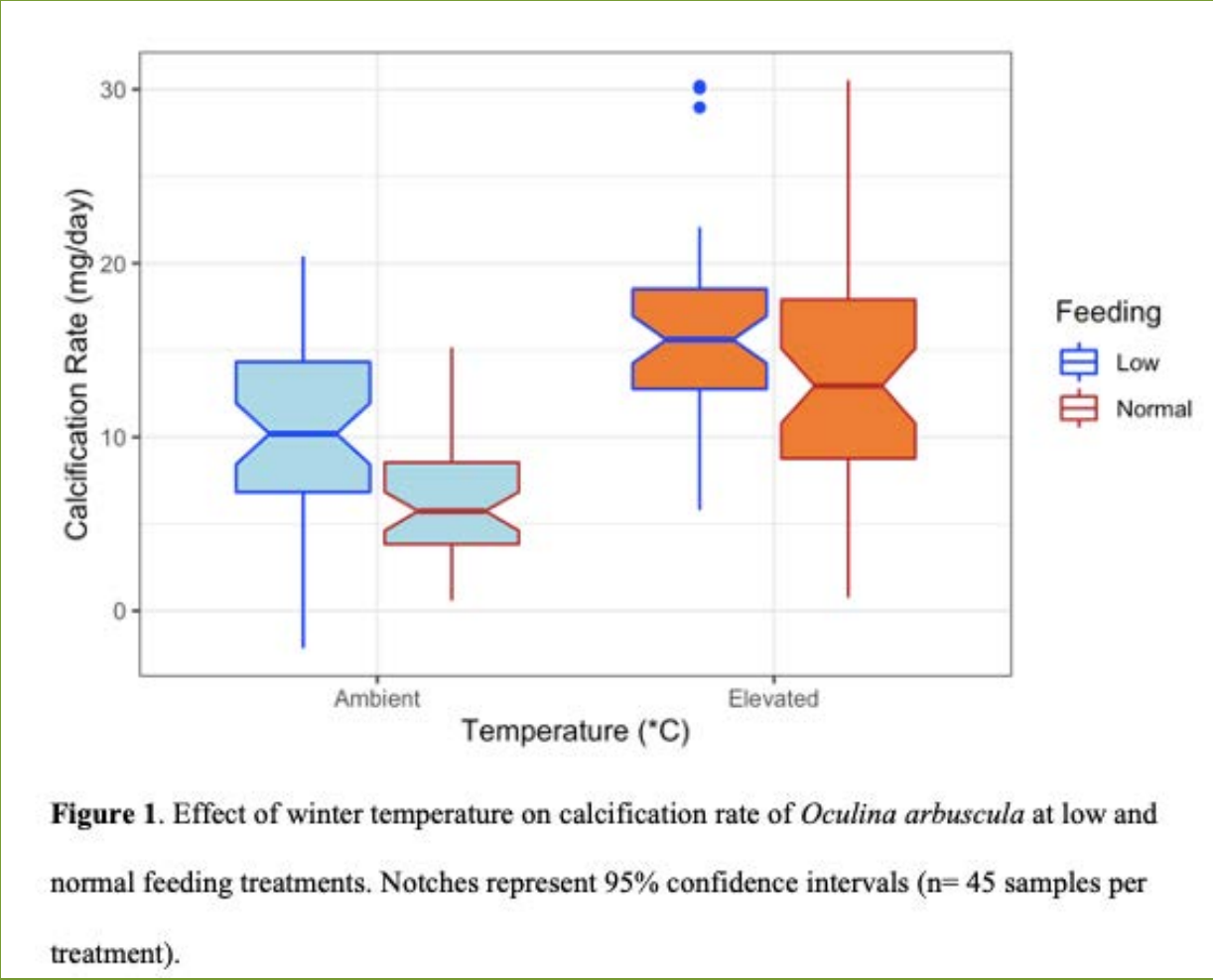
Figure 1. Effect of winter temperature on calcification rate of *Oculina arbuscula* at low and normal feeding treatments. Notches represent 95% confidence intervals (n= 45 samples per treatment).

Calcification Rates Were Positive Over Each Experimental Interval

Over both observational intervals (i.e., 0-30 days and 31-60 days), corals reared at warmer winter temperatures exhibited higher calcification rates regardless of feeding treatment. In addition, corals in all treatments maintained calcification over the first 30 days of the experiment and this consistent calcification trend persisted through the end of the experiment (Figure 2).
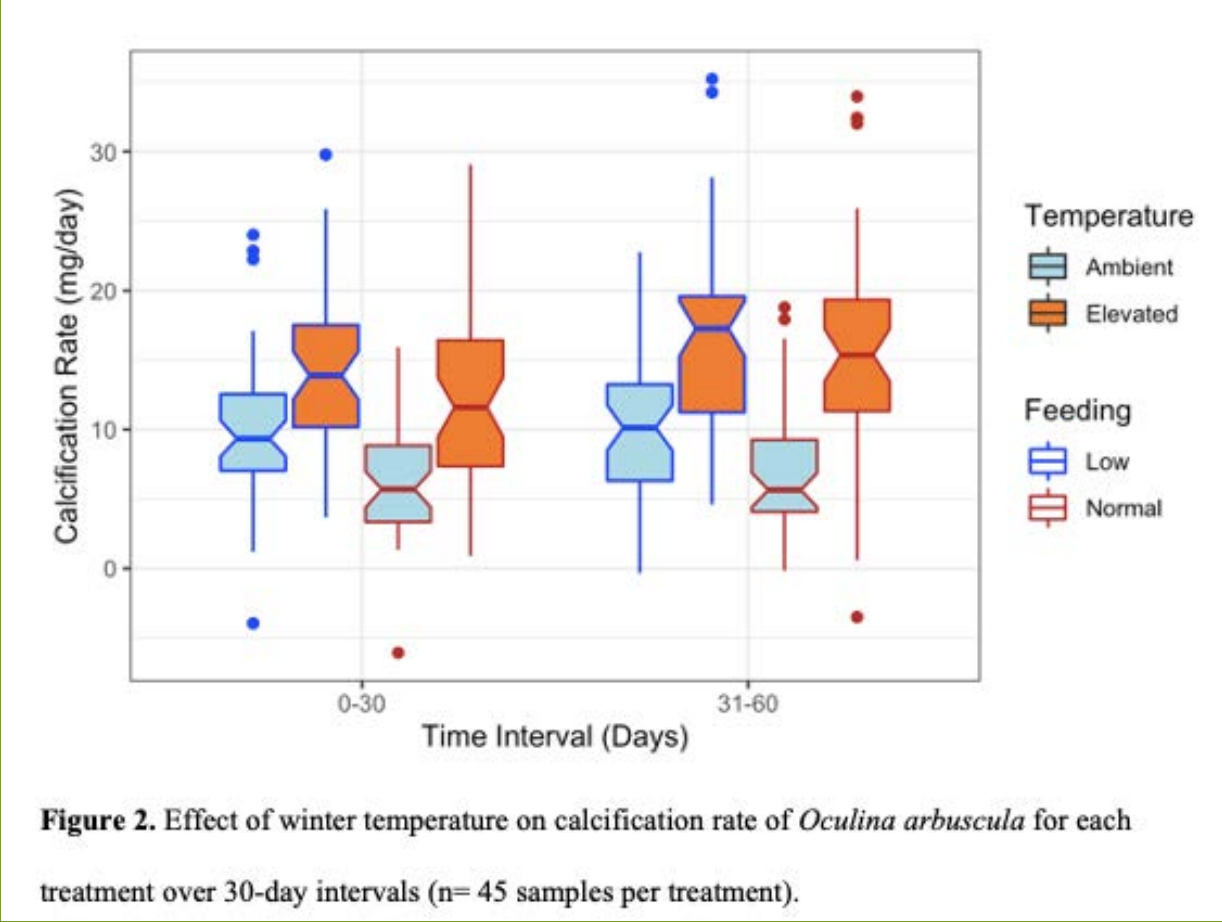
Figure 2. Effect of winter temperature on calcification rate of *Oculina arbuscula* for each treatment over 30-day intervals (n= 45 samples per treatment).

DISCUSSION

Elevated Winter Temperatures Offer Potential Advantage to Corals for Winter Calcification Rates

This experiment shows that Oculina arbuscula calcified at a greater rate under future elevated winter temperatures than at current seawater temperatures. The difference in dry weight change between the ambient and elevated temperatures for both low and normal feeding conditions was significant, indicating warmer temperatures benefit the corals' calcification rates. This is likely due to higher metabolic rates at warmer temperatures since O. arbuscula is known to grow four times faster in the summer than during the winter (Miller, 1995). Additionally, current seasonal temperature changes result in undersaturated aragonite concentrations in the ocean during the coldest period of the year (Ries et al., 2010), meaning corals have less aragonite to perform calcification during the winter. Elevated winter temperatures would likely mean increased aragonite saturation, enabling corals to calcify more in these conditions. Therefore, increased aragonite availability, along with a higher metabolic rate from warmer winter temperatures, could explain why O. arbuscula had higher rates of calcification in the elevated winter temperature treatment.

Heterotrophy Has Little Impact on Calcification Rates

Heterotrophy appears to have no benefits to calcification rates in O. arbuscula for either temperature treatment, and even potentially hinders calcification since corals reared at low feeding conditions grew faster in both temperature treatments than corals reared at normal feeding conditions. This indicates that O. arbuscula likely relied more heavily on its symbionts for nutrition than on heterotrophic food sources. Symbiodinium type B2, now genus Breviolum (LaJeunesse et al., 2018), is the only symbiont present in O. arbuscula. This symbiont is physiologically tolerant to cold stress and rapidly recovers from prolonged exposure, functioning minimally at temperatures as low as 10°C (Thornhill et al., 2008). Since the treatment temperatures were above this lower threshold, Breviolum was actively photosynthesizing to provide nutrition to the coral, allowing it to calcify under the winter conditions. Therefore, autotrophic food sources played a larger role in the calcification rates of O. arbuscula than heterotrophy.

Implications for Future Climate Change Predictions

In the temperate coral *O. arbuscula*, Aichelman et al. (2016) found that under summer thermal stress, greater net calcification occurred in corals fed heterotrophically than in those unfed, indicating that heterotrophy can mediate the negative effects of temperature stress on calcification. In the predicted elevated winter temperature used for this experiment, *O. arbuscula* exhibited greater net calcification regardless of heterotrophic feeding levels. This suggests that the winter season may become the optimal time for growth under future climate change conditions as corals do not appear to exhibit a stress response during periods of warmer winter seawater temperatures. If corals continue to grow more quickly during the winter from these elevated temperatures, this may allow for a large portion of recovery from the effects of thermal stress in the summer to now occur in the winter. Together, these responses may lead to a shift in the seasonal pattern of coral growth with the winter becoming the main period for growth and the summer shifting to an inactive period so corals can survive the added stress from summer thermal events predicted with climate change.

CONCLUSION

Although many studies evaluated how heterotrophy affects corals under summer thermal stress, none have looked specifically at the effects of elevated winter warming on temperate corals. This study aimed to understand how Oculina arbuscula responds to winter warming and if heterotrophy played a role in its physiological response. The results of this experiment show that heterotrophy did not impact calcification rates of Oculina arbuscula, but rather that elevated winter temperatures cause faster growth during the winter season. Future studies should focus on the relationship of summer and winter thermal stress to understand the response of O. arbuscula on a yearly scale.

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About the Author

Tyler Christian is a senior Biology major with minors in Marine Science and Environmental Science. She is from Hutchinson, KS, but has moved around most of her life. She first became involved with research after taking an introductory course in marine science the first semester of her freshman year. She quickly realized her passion for marine science through the course and became involved in the Castillo Lab after asking the professor, Dr. Castillo, if there were any volunteer positions available for students. She began with general coral care and tank maintenance, and eventually worked her way up to conducting her own experiment investigating the effects of winter ocean warming on the NC coral species, Oculina arbuscula, in Spring of 2019. Since then, she's been involved in the Kingsolver Lab performing colony care for horn worms and the Lohmann Lab caring for loggerhead sea turtles through the work study program. Meanwhile, she has also been analyzing the data from her coral experiment with the intention of publishing her work in a scientific journal upon her graduation in May 2021. She plans to take a gap year before pursuing a doctorate in marine biology.

Ecological Role of a Cosmopolitan Testate Rhizopod, Paulinella ovalis, in the Microbial Food Web of a Eutrophic Estuary

by Luke Townsend

Paulinella ovalis is a heterotrophic nanoplanktonic rhizopod abundant in estuarine and coastal waters. In the microbial food web, heterotrophic nanoplankton (HNP) consume picophytoplankton and are grazed by larger heterotrophs–recycling organic matter and transferring carbon to higher trophic levels. This generalization of HNP's food web role is based primarily on studies of heterotrophic nanoflagellates (HNF). Little is known about the function of P. ovalis, but this study hypothesizes a similar role to HNF based on analogous size (four-microns) and trophic mode. This study assesses the hypothesis by examining the spatial and seasonal distribution of P. ovalis and its picocyanobacterial prey in the Neuse River Estuary (NRE), by measuring its growth rates, and estimating its potential grazing pressure on picocyanobacteria. P. ovalis abundance paralleled that of picocyanobacteria with higher abundance in warmer, saltier waters. P. ovalis growth rates ranged from -0.11, 0.25, and 0.43 per day–establishing a minimum growth rate of at least 0.3 d-1. Based on a 0.3 d-1 growth rate and assuming a biomass yield of 0.3 from literature values, P. ovalis has the potential to consume ~48% of the picocyanobacteria population per day. Since ~50% of primary production in the NRE is produced by picocyanobacteria, it is possible that 25% of primary production is consumed by P. ovalis. These estimates demonstrate the potential importance of P. ovalis within the microbial food web, and should motivate future studies to directly measure the grazing rates by and on P. ovalis to further assess its role in the food web.

Keywords: rhizopod, microbial food web, growth, estuary, picocyanobacteria

INTRODUCTION

The microbial loop, composed of both autotrophic and heterotrophic unicellular organisms (phytoplankton, bacteria, and flagellates), is an essential part of a marine ecosystem's foundation (Azam et al., 1983; Sherr and Sherr, 1988). Within this microbial loop, phytoplankton fix carbon and produce dissolved organic matter (DOM) that can then be up-taken by bacteria as a source of energy (Azam et al., 1983; Sherr and Sherr, 1988). Flagellates will then consume these bacteria along with autotrophic cyanobacteria to obtain the DOM-produced energy (Azam et al., 1983; Sherr and Sherr, 1988). At first, the microbial loop was believed to be a confined loop solely consisting of pico and nanoplanktonic microbes that processed organic material which was not accessible to higher trophic levels (Azam et al., 1983; Sherr and Sherr, 1988). However, it is now widely accepted that nanoplanktonic heterotrophs (HNP) link the microbial food web to higher trophic levels by consuming picoplankton and being subsequently grazed by omnivorous zooplankton–allowing organic matter that would be unattainable to marine megafauna to be available (Sherr and Sherr, 1988). As a result, the quality of coastal waters is positively enhanced by HNP connecting the microbial food web to higher trophic levels, for when there is no link between HNP and autotrophic plankton, cyanobacterial blooms occur–harming marine organisms such as sponges and seagrasses (Butler et al., 1995; Goleski et al., 2010). It is therefore vital to study the interactions between the microbial loop and HNP to understand the nature of marine food webs.

Most of what we know about HNP comes from studying heterotrophic nanoflagellates (HNF) which play a major role in microbial consumption and zooplankton production (Weisse and Moser, 1991; Weisse, 1997). However, there are organisms other than flagellates that possibly fulfill the same role. Paulinella ovalis is a nanoplanktonic, phagotrophic testate rhizopod that is cosmopolitan in productive coastal and estuarine waters (Johnson et al., 1988). In the early 1900's, Wulff mistakenly identified P. ovalis as Calycomonas ovalis due to its similar morphology to the uniflagellated, chrysophyte Calycomonas gracilis (Campbell, 1973). Recently, however, studies of its ultrastructure by transmission electron microscopy led to the protist being reassigned to the genus of testate rhizopods, Paulinella (Johnson et al., 1988). In terms of appearance and size, the testate rhizopod is ~4 microns in length with scales surrounding its exterior, resembling a grenade-like shape (Figure 1). Johnson et al. (1988) observed few heterotrophic bacteria and an abundance of Synechococcus organisms inside the food vacuoles of P. ovalis–inferring that Synechococcus is the testate rhizopod's preferred prey. We are fortunate to have information regarding P. ovalis's abundance since its misidentification as a phytoplankton led to long term phytoplankton monitoring programs keeping track of the testate rhizopod's abundance. P. ovalis is incredibly abundant in waters

throughout the world from the coasts of New Zealand to the United States of America, and it is often the dominant eukaryotic plankton observed in estuarine and coastal waters (Johnson et al., 1988). Specifically, P. ovalis in the St. Martin River of Maryland's coastal waters was 24% of the total "phytoplankton" group, it was the dominant microorganism in the estuarine waters of Maryland's Chincoteague Bay in 2004 by making up to 50% of total nanoplankton, and the testate rhizopod was found in 83% of all samples collected in South Creek, North Carolina (Deonarine, 2006; Stanley and Daniel, 1985; Tango et al., 2004). Besides its abundance and preferred prey, there is little information known regarding the phagotrophic species.

Table 1. The growth rates, yields, and biomass-specific consumption rates for a wide variety of phagotrophs in the microbial food web.

Phagotroph Group	Growth Rate (d^{-1})	Gross Growth Efficiency	Biomass-Specific Consumption Rate (d^{-1})	Reference
Heterotrophic Microflagellates	2.40-6.00	~0.24-0.49	10.00-10.80	Sherr and Sherr, 1983; Fenchel, 1982
Heterotrophic Nanoflagellates	2.40-6.00	~0.40-0.60	6.00-10.00	Tophoj et al., 2018
Loricate Choanoflagellate	1.80	0.27	6.67	Geider and Leadbeater, 1988
Ciliates	1.06	0.40	2.65	Hansen et al, 1997
Rotifers	0.48	0.29	1.66	Hansen et al, 1997
Heterotrophic Dinoflagellates	0.46	0.40	1.15	Hansen et al, 1997

The objectives of this study were to determine the growth rate of P. ovalis, its spatial and seasonal distribution in the Neuse River Estuary (NRE) in relation to its prey, and estimate its potential grazing pressure on picocyanobacteria based on an assumed growth yield and overlapping patterns of abundance–elucidating the significance of the rhizopod in the microbial food web. HNF have rapid growth rates (2.40 to 6.00 d^{-1}), ingestion rates(~473 bacteria d^{-1}), and high gross growth efficiencies (~0.40 to 0.60 per unit biomass) (Table 1) (Tophoj et al., 2018; Weisse and Moser, 1991). Based on these growth rates and yields, HNF have the potential to consume 6.00 to 10.00 fractions of their weight per day (Table 1). In comparison to HNF, slower growing heterotrophs such as rotifers and dinoflagellates consume less prey per day per predator biomass (Table 1). Therefore, fast growth rates require high consumption rates. In effect, assuming P. ovalis has a fast rate of growth, there could be a possible association between their rapid growth rate and rhizopod consumption of picoplanktonic cyanobacteria–having a significant impact on the microbial food web.

While the growth rate of *P. ovalis* has not been directly measured, other photosynthetic organisms of the genus have been studied with slower growth rates at ~0.12 per day (Gabr et al., 2020). Because *P. ovalis* has a trophic mode similar to HNF, this study hypothesizes that they would have similar growth rates–differentiating the testate rhizopod from its congeners. Jeong et al. (2010) compared the growth rates of heterotrophic dinoflagellates to photosynthetic dinoflagellates and found that the heterotrophs grew faster than the autotrophic organisms. In effect, it is possible for the heterotrophic *P. ovalis* to grow faster than its photosynthetic, mixotrophic relatives. Furthermore, the NRE system has a large abundance of picophytoplankton within its waters (42-55 percent of total primary productivity), specifically *Synechococcus* were the most dominant of the picophytoplankton at ~1,000,000 cells per mL (Gaulke et al., 2010; Paerl et al., 2020). This provides a constant food source for the rhizopod–allowing *P. ovalis* to grow at a steady rate within the estuarine system–which is why HNP populations are generally thought to be under top-down control.

In terms of spatial and seasonal distribution, this study

hypothesizes that P. ovalis would have a similar distribution to that of its prey Synechococcus with the picoplanktonic cyanobacteria inhabiting warmer, more saline waters (Paerl et al., 2014; Pinckney et al., 1998). There is limited evidence to support this hypothesis, but it has been observed that P. ovalis was the dominant microorganism during the summer months in South Creek of the Pamlico River Estuary of North Carolina (Stanley and Daniel, 1985). Furthermore, P. ovalis is a marine organism, and we would expect to find the testate rhizopod in more saline waters. A significant overlap in the distribution of P. ovalis and its prey would enhance predation. As a result, there would be an increase in the transfer of nutrients up to higher trophic levels (Stoecker et al., 1984).

MATERIALS & METHODS

Paulinella ovalis growth rates were measured from plankton samples collected in the NRE system based on changes in cell abundance over a 24-hour incubation period. Additionally, the spatial and seasonal distributions of *P. ovalis* were determined by analyzing cell abundance and physical environmental data from the North Carolina Department of Environmental Quality's ambient water monitoring system in the NRE.

Study site

The NRE is on the eastern coast of North Carolina that is classified as a bar-built estuary within the Albemarle-Pamlico Sound (Hall and Paerl, 2011). The lack of inlets into the NRE negate tides within the water body, but the aquatic system is circulated by freshwater inflow and wind-driven circulation–establishing a tributary, partially-mixed estuary (Hall and Paerl, 2011). Station 50 is found in the upstream portion of the NRE while Station 100 is found in the middle area of the estuary, and both stations experience fluctuations in salinity primarily due to freshwater inputs causing a barotropic pressure gradient force that transports salt throughout the water body (Figure 2). The stations have been monitored by the North Carolina Department of Environmental Quality (NCDEQ) who provide information regarding the environmental conditions of the NRE such as salinity, temperature, etc. (https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/ecosystems-branch/ambient-monitoring-system).

Growth rate determination

On September 16th, 2020 at station 50, a surface water sample was collected. On October 2nd, 2020 at station 100, two water samples were collected with one being at the surface (100S) and the other collected at the pycnocline (100P at ~1.5m depth) with a Van Doren water sampler. These water samples were collected in 20L polyethylene carboys. Salinity and temperature were measured using a YSI 6600 multiparameter water quality sonde. After the water samples were collected, they were transported back to the University of North Carolina's Institute of Marine Sciences where the sampled water was gravity filtered through a ten-micron mesh (Weisse, 1997) to remove potential predators of P. ovalis (Weisse, 1997). The growth rate experiment actually measures net growth, but I was interested in the testate rhizopod's intrinsic growth rate. The following equation represents the relationship between net and intrinsic growth:

Equation 1: Net Growth = Intrinsic Growth - Mortality

Since predation is the largest source of mortality, the elimination of mortality from the growth experiment would measure intrinsic growth since it would then equate to net growth. Thus, I tried to minimize mortality in the growth experiments by removing the predators of *P. ovalis* with the ten-micron mesh (Weisse, 1997). Filtered water from each site was added to triplicate 125mL HDPE bottles. A 20 mL subsample from each 125 mL bottle was poured into a 20mL scintillation vial where Lugol's solution (1% final concentration) was added to preserve P. ovalis for microscopic enumeration and examination. The 125 mL bottles were placed into an outdoor pond with flowing seawater to mimic natural temperature and light conditions. The bottles were covered with two layers of neutral

density screens to prevent damage from unrealistically high levels of UV light. P. ovalis samples grew for a specified period of time in the pond (28.5 hours for station 50 and 24 hours for station 100). The HDPE bottles were subsampled again and preserved with Lugol's solution to determine the growth of P. ovalis by changes in cell abundance. These vials were stored in the laboratory to be later examined for the enumeration of P. ovalis.

Cell abundances of P. ovalis were obtained by using the inverted microscope technique of Utermöhl (1958). Initially, a triplicate vial sample was poured into a settling chamber (15 ml, 5 cm height) that was allowed to settle for a 24-hour period. Despite the 24-hour settling period not providing sufficient time for all microorganisms and detritus to settle, the continued use of a proportionately equal-sized settling chamber and settling time allows the cell counts to be comparable amongst samples (Hall and Paerl, 2011). After the settling period was complete, the sample was examined underneath a Leica DMIRB microscope with a phase contrast and a 400x magnification. One-hundred fields were counted for all samples to provide a precise cell count of P. ovalis. While samples were being examined underneath the microscope, photographs of dividing cells were taken to demonstrate that P. ovalis was growing in the HDPE bottles with its prey (Figures 1 and 2). Some cells were observed to have clearly stained areas in the bottom of the test field while other cells were lacking a clear stain. Currently, it is unclear if the unstained cells were dead or alive, but they were counted with the rest of the P. ovalis cells.

The growth rate of P. ovalis was calculated by using a logarithmic growth rate function, which is shown below:

Equation 2: $r=[\ln(P_t/P_o)]/t$

Seasonal and spatial distribution of P. ovalis.

Cell abundance and environmental data were collected as part of the NCDEQ's ambient monitoring system (https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/ecosystems-branch/ambient-monitoring-system) at seven stations along the NRE (Figure 3). Temperature, salinity, pH, and chlorophyll *a* data were compared to cell abundance. The data collected ranges from the years 2000 to 2017 at all stations along the NRE system to provide an in depth and long-term analysis of the *P. ovalis's* distribution in relation to environmental conditions. This study investigated the spatial and seasonal pattern of the testate rhizopod in relation to its prey and used zeaxanthin as a proxy of picoplanktonic cyanobacteria biomass (Gaulke et al., 2010).

Rank correlations were used to determine relationships between *P. ovalis* cell density and environmental conditions–pH, temperature, salinity, and chlorophyll *a*. Boxplots were used to assess cell abundance, temperature, zeaxanthin concentrations, and salinity between different stations and months in the NRE. These analyses were conducted in the R computer program (R Core Team, 2020). Rank correlations were considered significant if p < 0.05.

Figure 2. The locations of NCDEQ's seven ambient water monitoring stations in the Neuse River Estuarine system.

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RESULTS

Spatial and seasonal distribution of Paulinella ovalis

Paulinella ovalis was found at measured temperatures of ~5°C to 30°C, but the testate rhizopod tends to be more abundant in warmer waters which drove a weak, positive correlation with temperature (Rs = 0.23, p =1.1·10-13). This is illustrated by a cluster of high cell density values near 10,000 cells per mL in warmer waters between ~27°C to 30°C (Figure 4). *P. ovalis* has a positive correlation with pH at a wide range of variability from 6.5 to 9.0 pH (Rs = 0.44, p < 2.2·10-16). The testate rhizopod mainly inhabits areas that have pH values ranging from 7.5 to 8.5, and it has the highest cell density at ~8.0 pH (Figure 5). There is a weak positive correlation between P. ovalis and chlorophyll a concentration, despite the data points appearing to show no relationship (Rs = 0.27, p <2.2·10-16). The rhizopod inhabits waters with chlorophyll a concentrations ranging from one to ~100 µg/L with the highest cell density occurring at ~50 µg/L (Figure 6). The positive relationship between chlorophyll a concentrations and P. ovalis is probably driven by zero abundance values being paired with low chlorophyll a values, which are shown at the bottom of the figure (Figure 6). P. ovalis has an asymptotic, positive correlation with salinity (Rs = 0.66, p < 2.2·10-16) with its cell density increasing as salinity increases to ~10 but then leveling off at ~10,000 cells/mL (Figure 7).
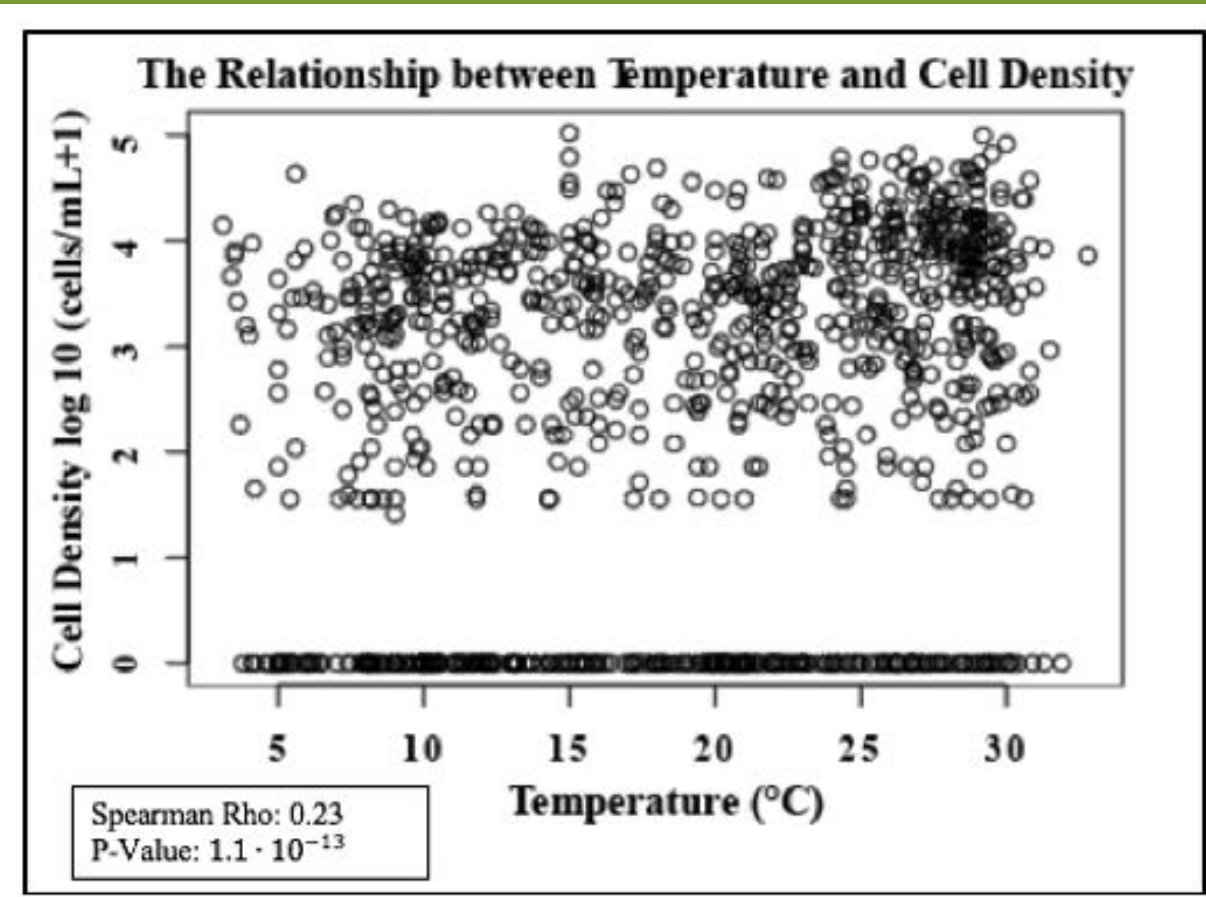

Figure 4. The relationship between temperature and cell density of *P. ovalis*. The zero values are data points where the cell density of *P. ovalis* was not counted on a given day.
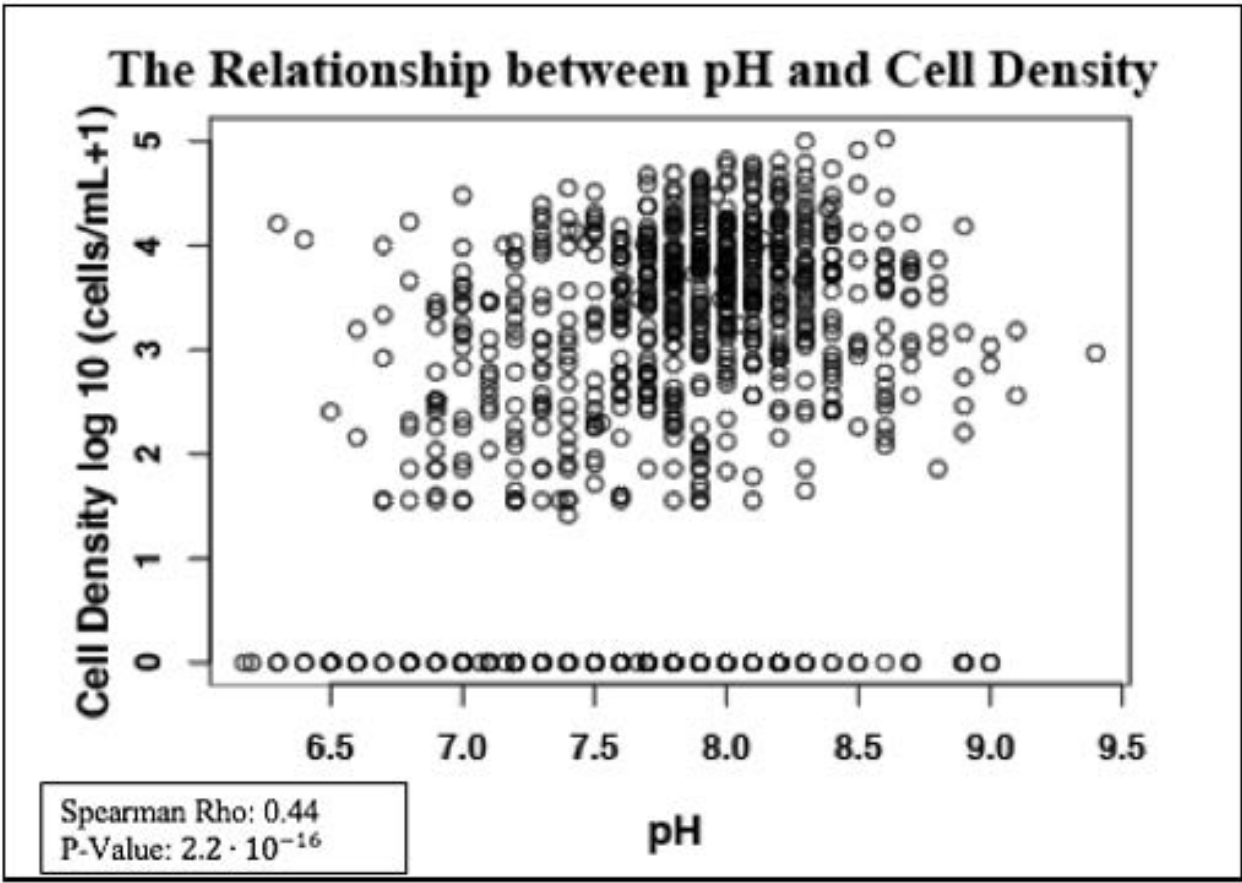

Figure 1. Image showing the division of *Paulinella ovalis* cells–illustrating growth.

Figure 5. The relationship between pH and the cell density of *P. ovalis*. The zero values are data points where the cell density of *P. ovalis* was not counted on a given day.
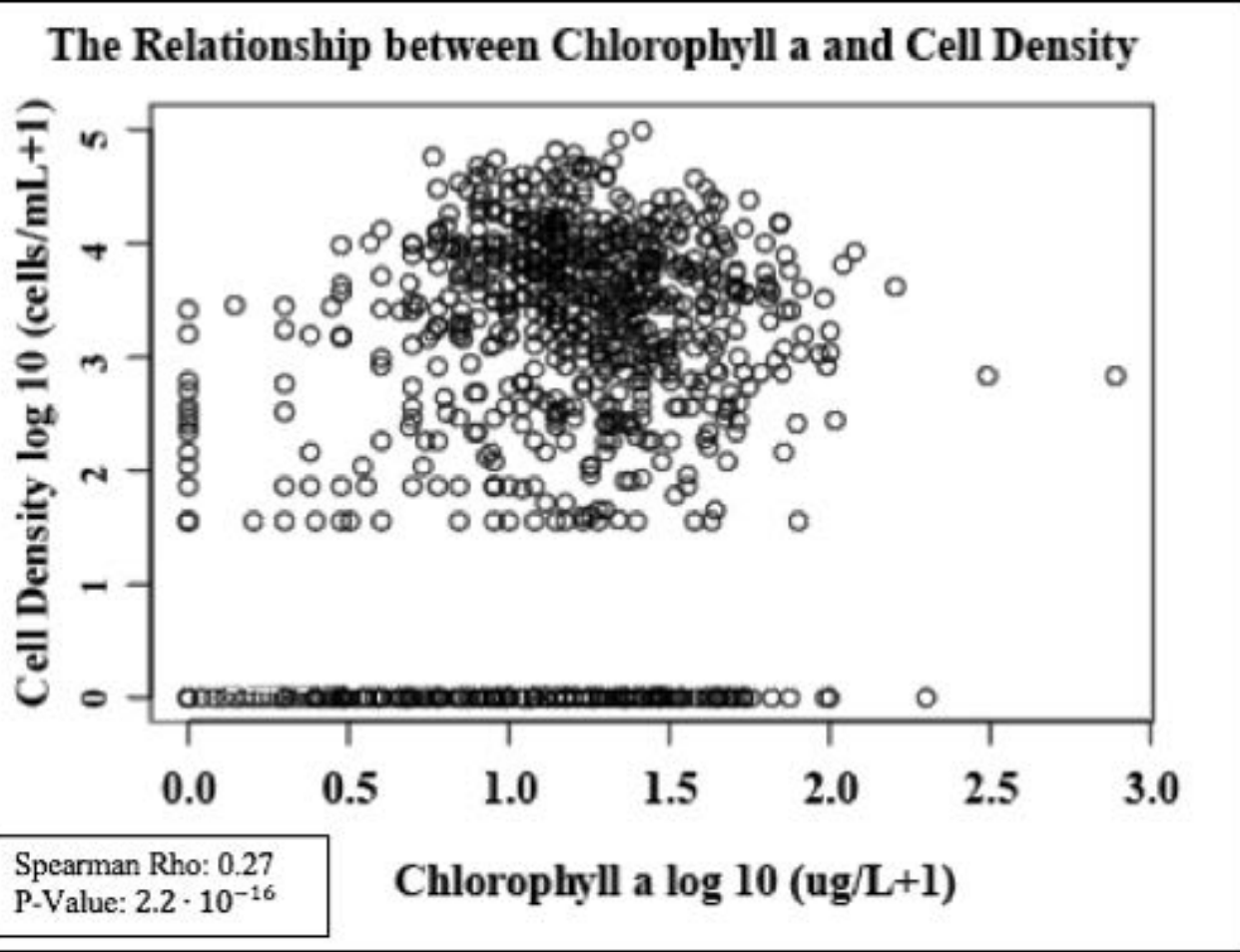

Figure 6. The relationship between chlorophyll *a* and the cell density of *P. ovalis*. The zero values are data points where the cell density of *P. ovalis* was not counted on a given day.
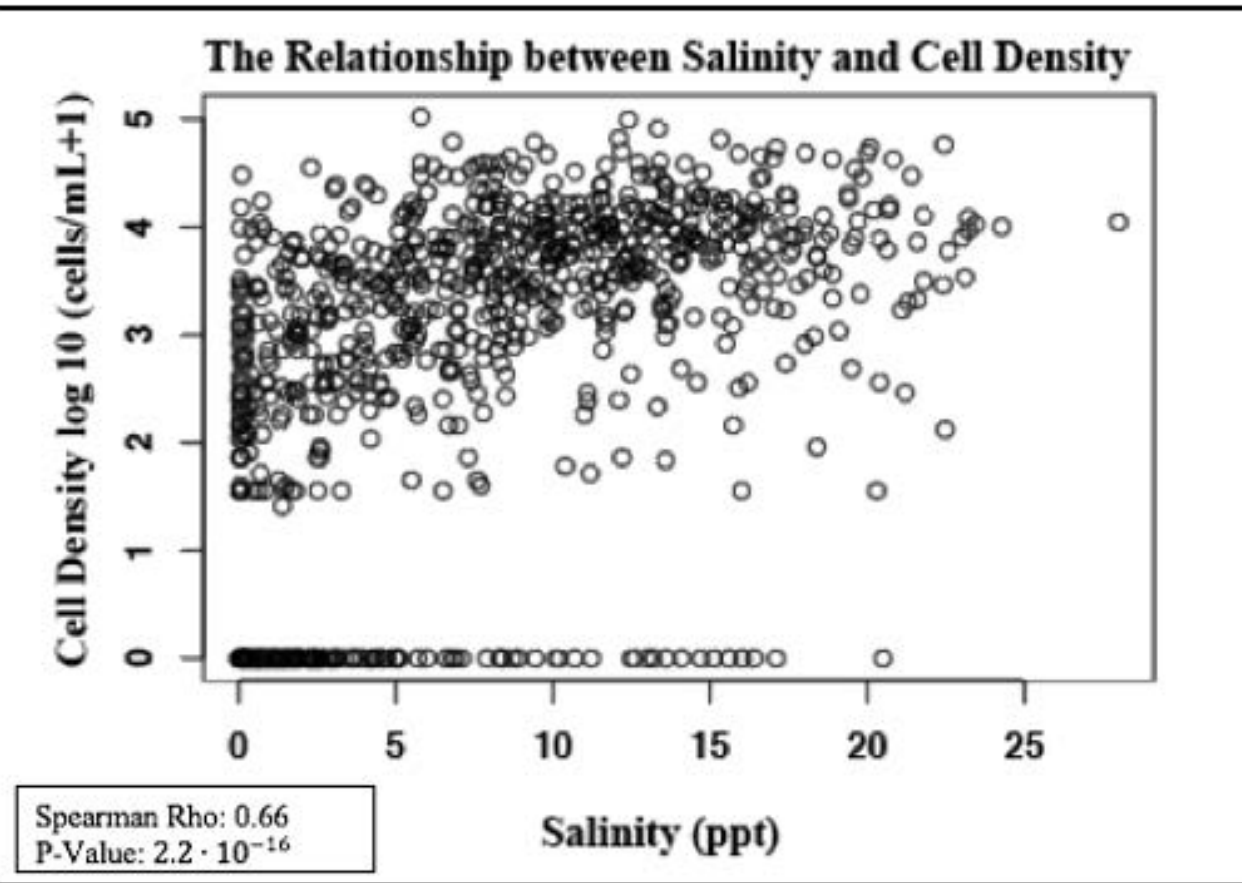

Figure 7. The relationship between salinity and cell density of *P. ovalis*. The zero values are data points where the cell density of *P. ovalis* was not counted on a given day.

The median cell density of P. ovalis increases from the upper ambient monitoring stations (7930000, 8570000, and 8902500) of the NRE to the lower stations (8910000, 9530000, 9810000, and 9930000) where it maintains a constant cell density at ~10,000 cells/mL (Figure 8). It is as expected that zero cell density values are due to freshwater inputs flowing into the upper portion of the NRE with the upper station being 100% freshwater nearly all the time (Paerl et al., 2020). The salinity gradually increases from the ambient monitoring stations in the upper portion of the NRE to the stations located in the lower portion of the NRE (Figure 8).
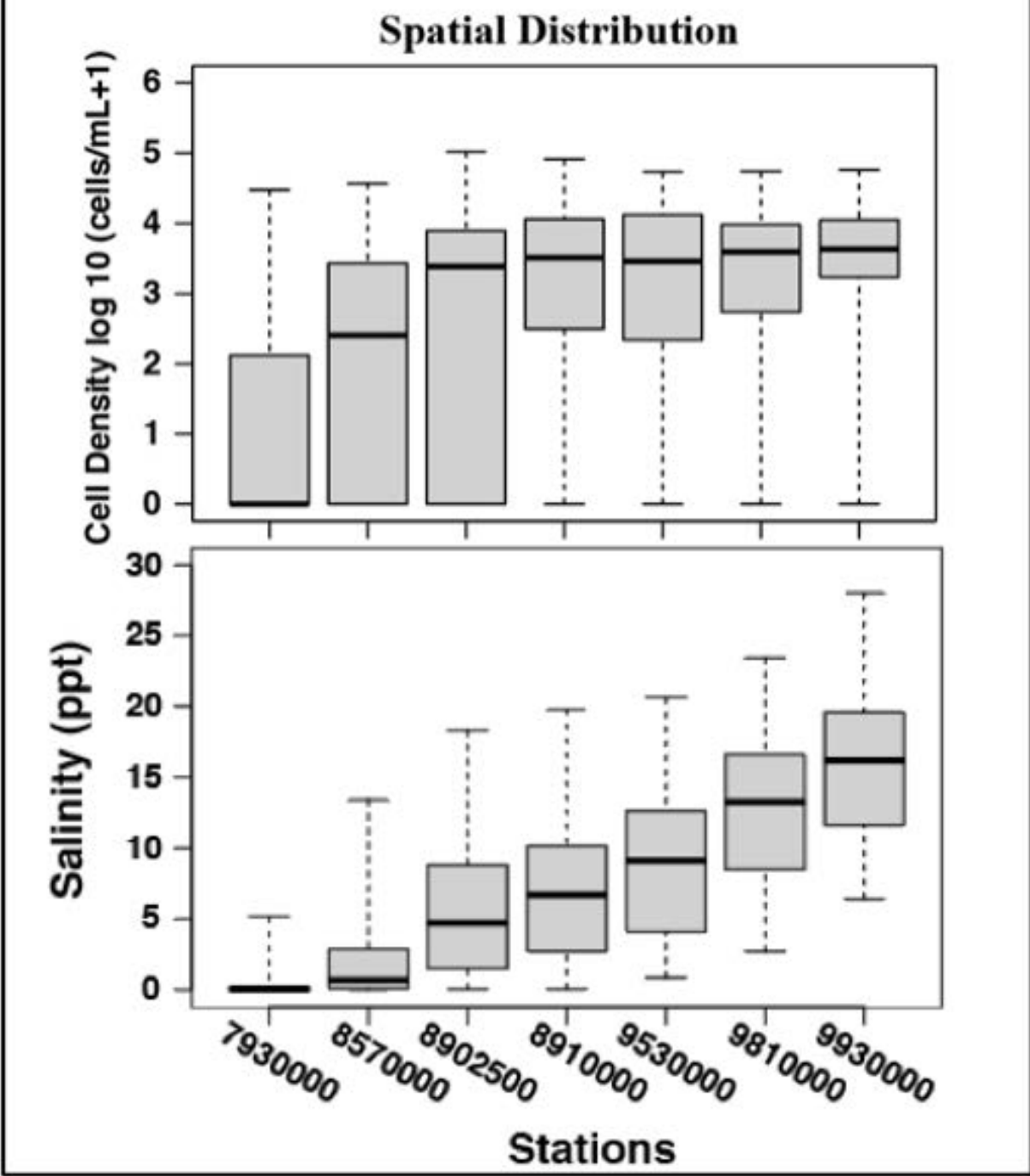
Figure 8. Spatial distribution of *P. ovalis* and salinity in NRE from upstream (7930000) to downstream (9930000).

The median cell density of P. ovalis exhibits a clear seasonal cycle with an increase preceding the summer months starting in April–reaching a maximum density at ~10,000 cells/mL in August–and decreasing during the winter months following August in the NRE (Figure 9). The temperature sharply increases in the NRE starting in March at ~13°C, climaxing in July ~30°C, and dropping back to ~13°C in the months following July which can be shown by the median values following this inverted parabolic trend of increasing to a peak along a curve then decreasing (Figure 8). Monthly median concentrations of zeaxanthin, a proxy for picocyanobacterial biomass, follow the same inverted parabolic trend of temperature in the NRE by increasing in March, peaking in June, and decreasing in cell density following the month of June (Figure 9). P. ovalis does follow this pattern for the most part, but the testate rhizopod does experience a lag in the spring by a couple of months with it experiencing its greatest increase in May instead of in March (Figure 9).
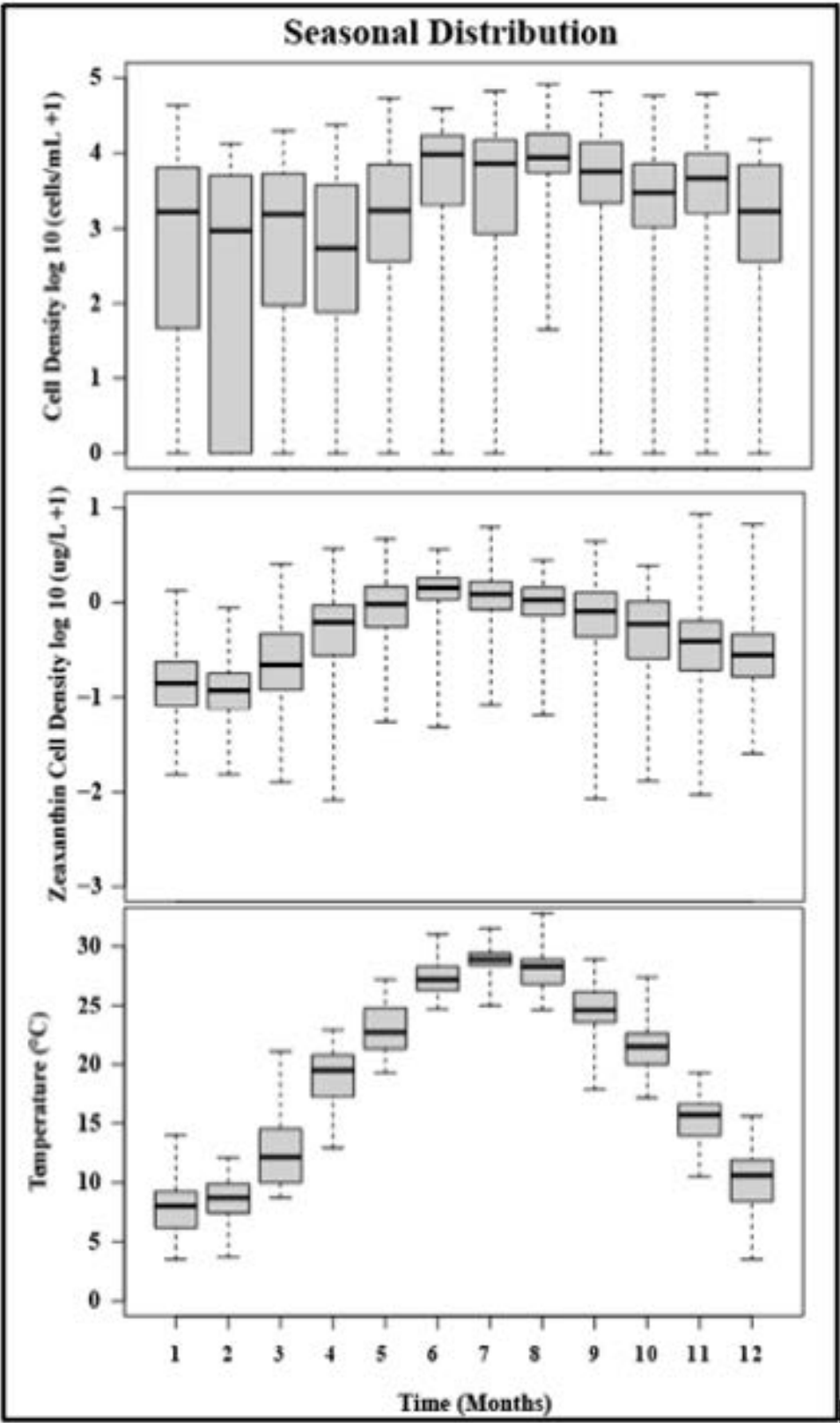

Figure 9. Seasonal distribution of *P. ovalis*, zeaxanthin, and temperature in the NRE.

Paulinella ovalis growth rates

In the station 50S experiment, the *P. ovalis* population grew in two triplicate subsamples [50S (1) and 50S (2)] while the other subsample [50S (3)] experienced a decrease in population size–resulting in a negative growth rate, on average (Figure 10). From the September 18th and 19th triplicate set (50S), the growth rate of *P. ovalis* ranged from -0.45 to 0.06 per day. This equates to an average growth rate of -0.11 per day for *P. ovalis* at station 50S. It is noteworthy that the 10-micron mesh filters did not remove all predators because dinoflagellates were observed in all experiment samples.

Table 2. The salinity and temperature measurements at each station.		
Station	Salinity (ppt)	Temperature (°C)
50S	5.9	25.7
100S	8.6	21.9
100P	11.3	22.2

In the station 100S and 100P experiments, *P. ovalis* abundance increased in all triplicate subsamples at station 100–resulting in a positive growth rate, on average (Figure 11). The October 2nd and 3rd triplicate sets (100S and 100P) had growth rates ranging from 0.06 to 0.88 per day at the pycnocline (100P) and 0.07 to 0.54 per day at the surface (100S). The average growth rates from the 100P and 100S triplicate sets were 0.43 and 0.25 per day, respectively.
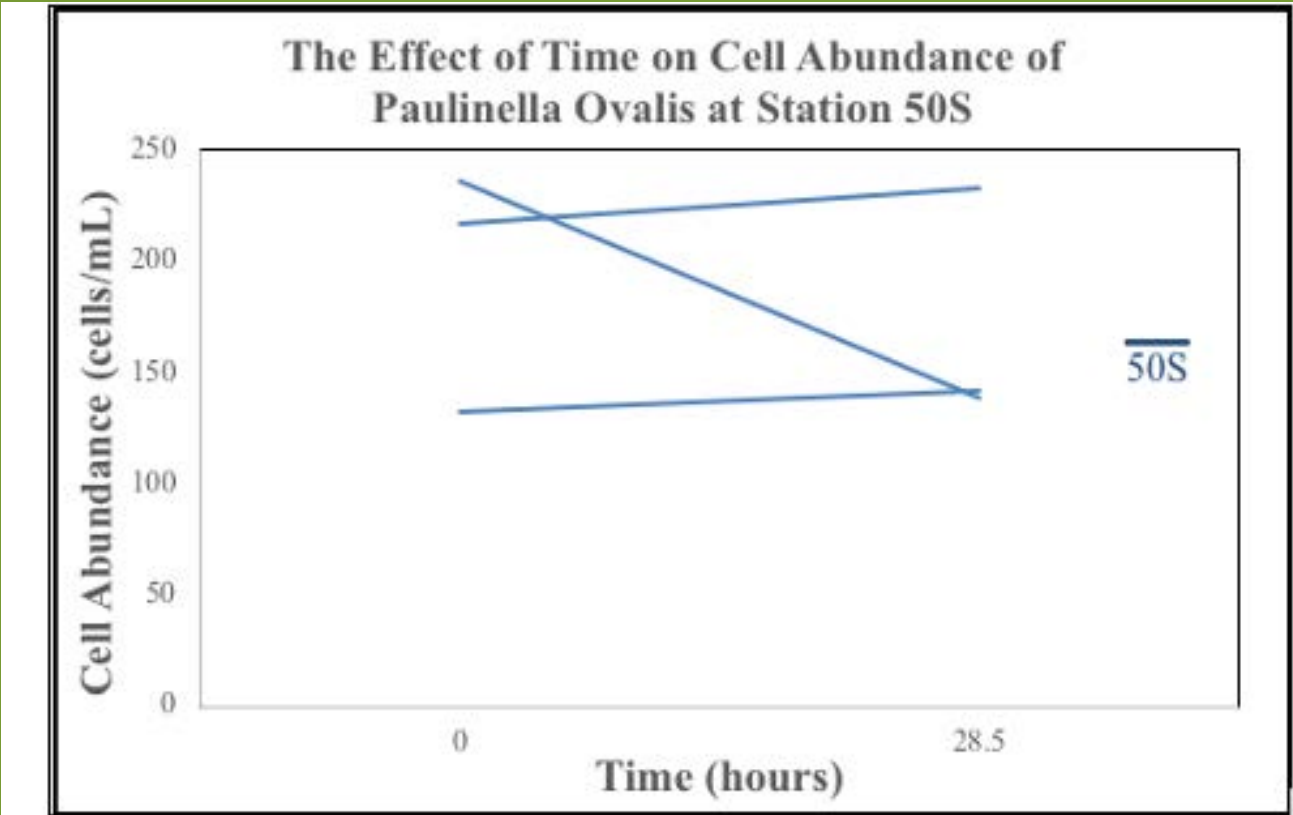
Figure 10. The effect of time on cell abundance of *P. ovalis* at station 50.
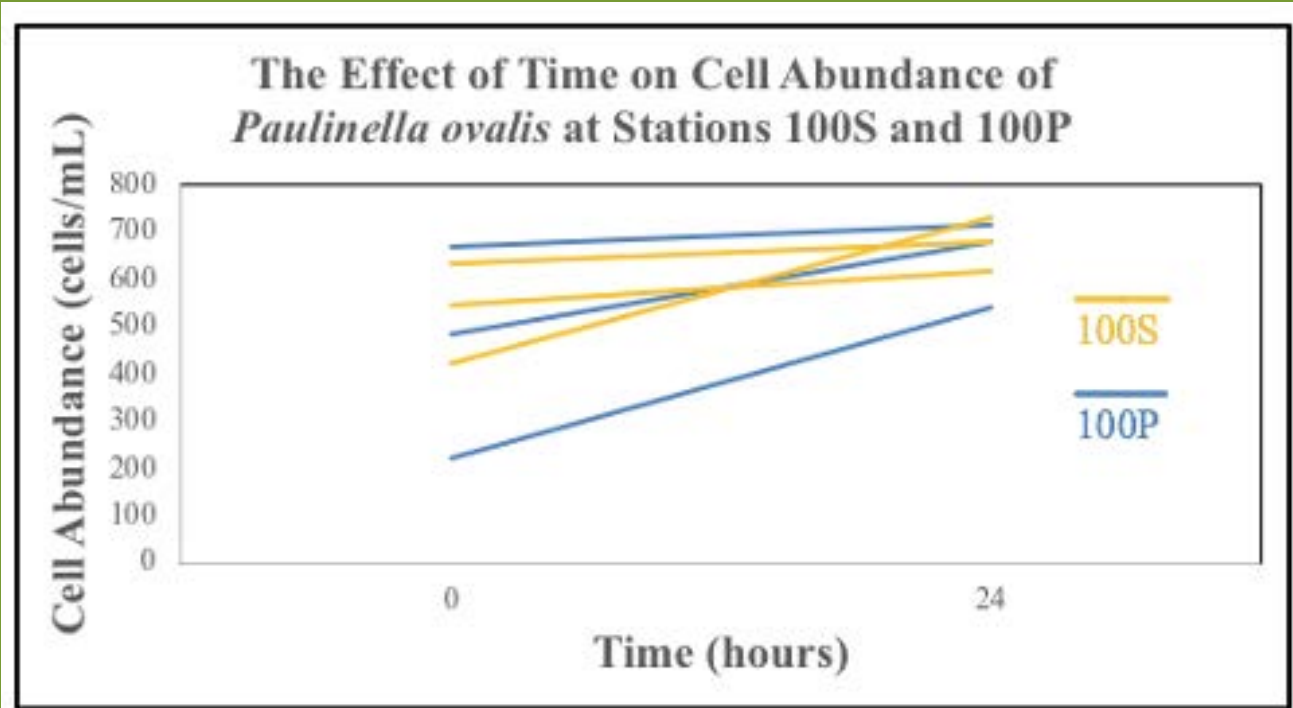
Figure 11. The effect of time on cell abundance of *P. ovalis* at station 100.

DISCUSSION

Growth rate of Paulinella ovalis

Based on the growth rate experiments, I found that *Paulinella ovalis* can grow at least as fast as 0.30 d-1. We know this is a minimum growth rate because I was unable to completely exclude all the potential grazers of *P. ovalis*. During the cell counts, dinoflagellates were observed in the samples–indicating that the 10-micron filter was not effective at removing all predators from the collected water samples (Figure 12 and 13). Heterotrophic and mixotrophic dinoflagellates consume a variety of prey that are similar in size to P. ovalis (Hansen et al., 1994). In the absence of mortality, the net growth rate equals the intrinsic growth rate determined by the rate of cell divisions, but the net growth rate is reduced by mortality from predation (Equation 1). Therefore, the observed net growth rate by P. ovalis underestimates intrinsic growth by an amount equal to the grazing rate, which was not measured

in this study. In future growth rate experiments, five-micron filters should be used as opposed to 10-microns because it would be more effective at removing predators from collected water samples to more accurately determine the growth rate of *P. ovalis*.
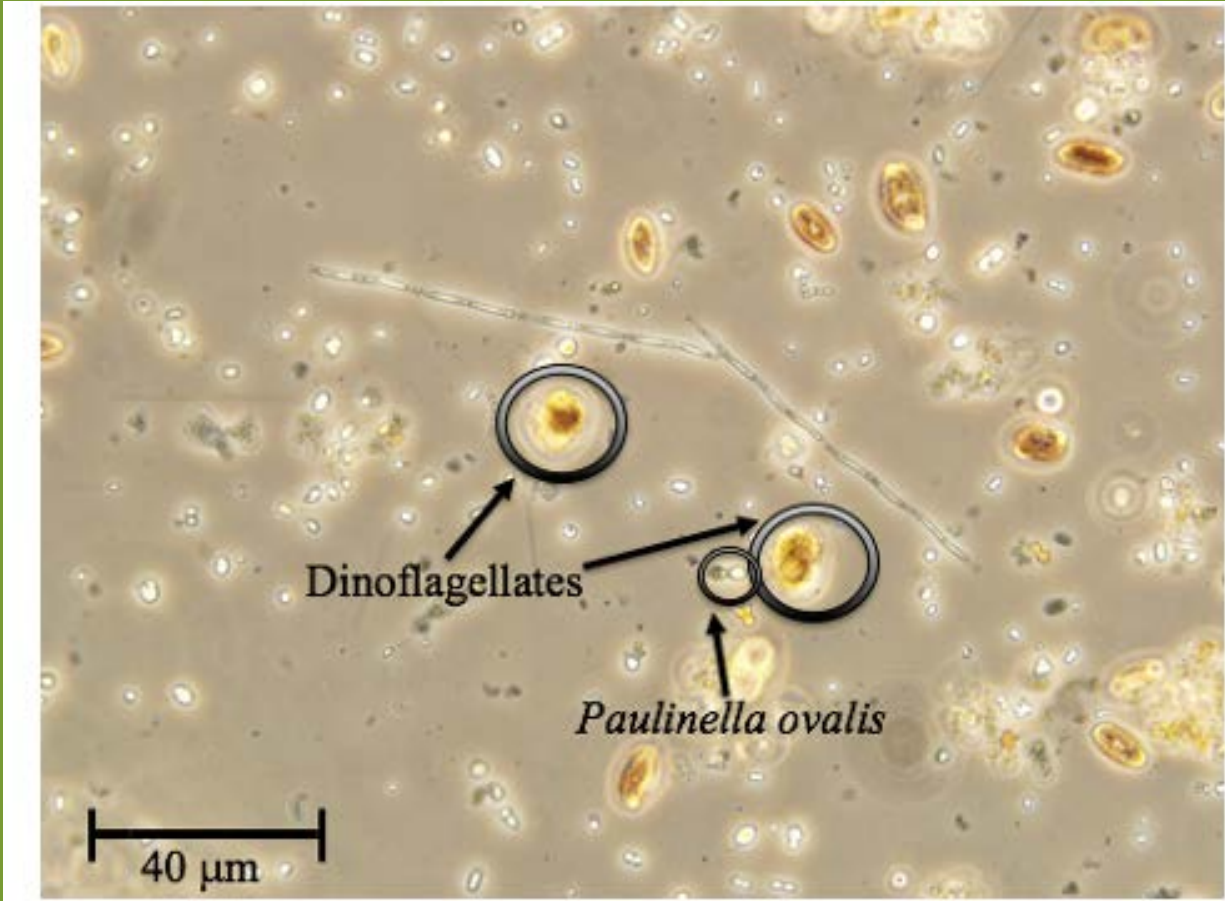

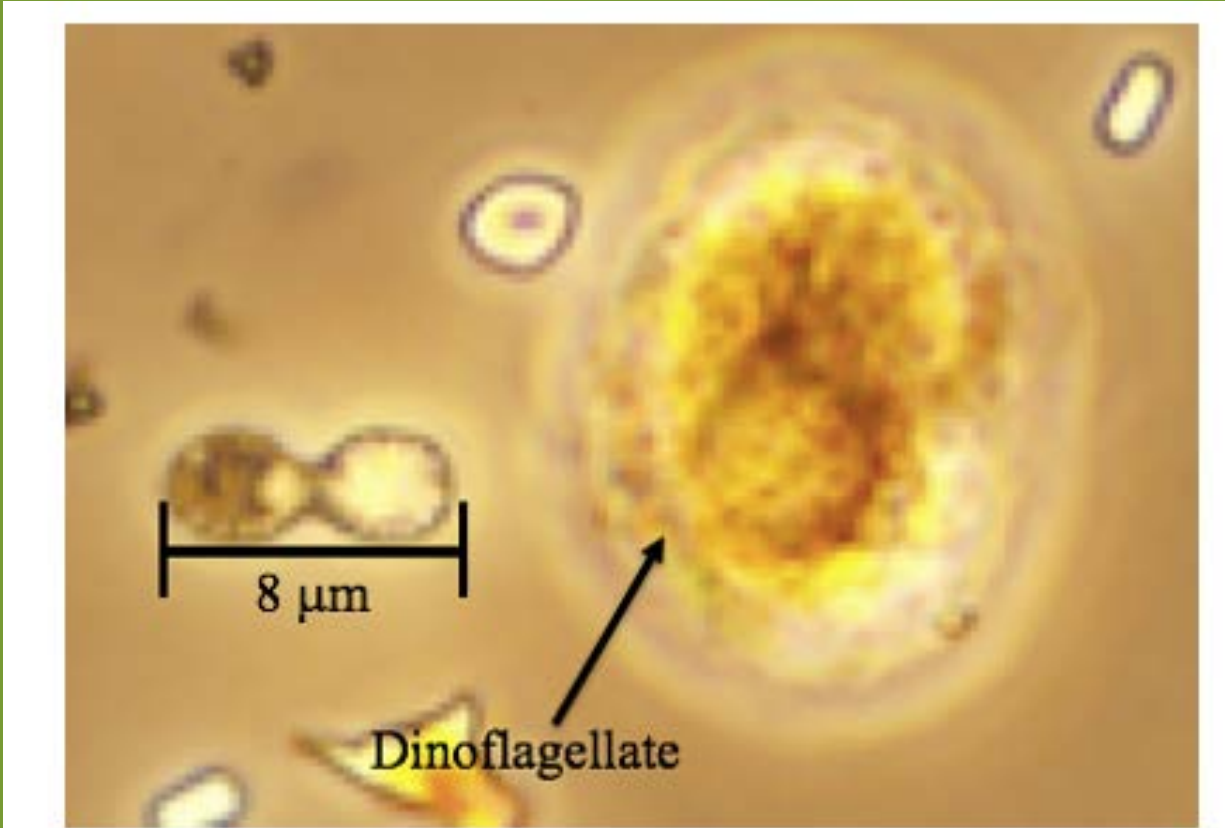Figure 12. Image of *P. ovalis* and dinoflagellates.

Figure 13. Image of dinoflagellate alongside *P. ovalis*

The initial hypothesis stating that *P. ovalis* has a similar growth to that of heterotrophic nanoflagellates could not be supported based on this studys' results. While the testate rhizopod does not grow as fast as HNF, *P. ovalis* does grow faster than other members of its genus by having a growth rate 2.5 times faster than the growth rate of the photosynthetic *Paulinella* members (Gabr et al., 2020). This is most likely due to the other *Paulinella* species having autotrophic lifestyles as opposed to heterotrophic consumption strategies like *P. ovalis* (Jeong et al., 2010).

Spatial and seasonal distribution of Paulinella ovalis

Upon reviewing the spatial distribution figures, this study's hypothesis can be supported with *P. ovalis* being located in more saline waters (Figure 7). This is further supported with the rhizopod having greater abundances at stations with higher salinities (Figure 8). Interestingly, the spatial distribution of *P. ovalis* shares a similar distribution with that of its prey because salinity has an asymptotic relationship with picophytoplankton biomass where biomass increases as salinity increases until it reaches a certain threshold (Paerl et al., 2014). We would expect to observe this similar, spatial distribution pattern between P. ovalis and its prey because the smaller plankton species are the food source of the heterotrophic rhizopod. It should be noted that the correlation between cell density and pH is driven by the covariation between pH and salinity with freshwaters generally having lower pH in the NRE (Van Dam and Wang, 2019). Additionally, the correlation between P. ovalis and chlorophyll a concentrations is driven by low chlorophyll a containing river water flowing into the estuary (Paerl et al., 2014).

Based on Figure 4, this study's hypothesis regarding the testate rhizopod inhabiting warmer waters can also be supported (Figure 4). When comparing the seasonal distribution of *P. ovalis* to temperature, however, the rhizopod experiences a

lag by a couple of months with the largest temperature increase occurring in March while P. ovalis cell density does not increase until May (Figure 9). Unlike P. ovalis, their picocyanobacteria prey do not experience a lag but rather increase in cell density with the increase in temperature in March (Figure 9). This is consistent with previous studies with picocyanobacteria abundance showing a strong response to temperature (Gaulke et al., 2010; Paerl et al., 2020).

Maximum growth rates of heterotrophic protists are generally positively related to temperature in the range observed for the NRE (~3°C to 32°C) (Hansen et al., 1997), and then can be reduced from maximum growth by prey scarcity (Hansen et al., 1997). As water temperature is increasing during the spring months, both food availability and temperature-controlled, maximum growth rates of P. ovalis are likely increasing. Cell abundance should increase too, unless mortality was unusually high for P. ovalis during this early spring period. This lag is possibly caused by high abundances of mixotrophic and heterotrophic dinoflagellates in the NRE during early spring (Pinckney et al., 1998) which may exert a strong top-down control on the testate rhizopod and prevent rapid population growth of P. ovalis during early spring.

Role of Paulinella ovalis in the estuarine food web

Based on the measured growth rate of *P. ovalis* and the measured concentrations of prey (*Synechococcus*) in the NRE, this study assessed the potential importance of grazing by *P. ovalis* on picoplanktonic cyanobacterial prey. Initially, I calculated the amount of new *P. ovalis* that would be produced after a day of growth based upon the exponential growth rate equation: $Pt=P0*e^{rt}$. I assigned the initial population value to be 10,889 (P0) which is based upon the average abundance of *P. ovalis* in the NRE at salinities above 10 ppt. Based on the minimum growth rate of 0.3 d-1, 3,809 new *P. ovalis* cells would be produced after a day of growth. This study assumed a growth yield of 0.3 biomass units of *P. ovalis* per biomass units of its *Synechococcus* prey (Hansen et al., 1997). Biomass of both *P. ovalis* and *Synechococcus* were estimated based on biovolume of spheres with 3.5 and 1.0 μm diameters, respectively. With calculated biovolumes of 18.8 and 0.5 μm3and the assumed growth yield of 0.3, 125 *Synechococcus* cells would need to be consumed to produce one new *P. ovalis* cell, or 477,471 *Synechococcus* cells to produce the 3,809 new *P. ovalis* cells each day.

Equation 3: Number of Paulinella cells*Volume of Paulinella Cell =
Prey Cells Eaten per Day *Volume of Prey Cell*Yield

⬇

Equation 4: (3809 cells)*(18.8um3)=(Prey Cells Eaten per Day)* (0.5um3)*0.3

⬇

Equation 5: Prey Cells Eaten per Day=477,471 cells

I then determined the amount of *Synechococcus* cells present in the NRE during the fall, on average. Based on a linear regression model produced by Gaulke et al. (2010) and past zeaxanthin (indicator of *Synechococcus*) concentration data, this study found that 1 million cells per milliliter of *Synechococcus* are found in the NRE (Gaulke et al., 2010; Paerl et al., 2020). Based on the fall growth rate and *Synechococcus* cell density, *P. ovalis* can potentially consume approximately half (480,000/1,000,000) of the picocyanobacteria standing stock every day. At the time of the growth rate experiment, it was fall and the water temperatures were cool, ~22°C (Table 2). When growing at an optimal temperature (~30°C), however, we would expect the growth rate of *P. ovalis* to be ~0.84 per day based upon a Q10 value of 2.8 (assuming ingestion and growth rate Q10 values are similar) and the following equation by Hansen et al, 1997:

Equation 6: log(r1)=log(ro)+logQ10*(t-t0)10

As a result, *P. ovalis* may consume ~165% of the *Synechococcus* standing stock per day during the summer. I am currently working on refining these estimates, but it appears that *P. ovalis* is a major grazer, possibly the primary grazer of picocyanobacteria in the NRE.

This study found that P. ovalis likely plays an important role in the microbial food web. The similar distribution patterns between the testate rhizopod and its prey indicate that there is a strong potential for predator-prey interactions. I speculate that predation by P. ovalis helps to recycle nutrients within estuarine systems by consuming picoplanktonic cyanobacteria in marine areas that receive minimal nutrient input from freshwater discharge–maintaining productivity in the microbial system. For instance, as salinity increases in estuarine systems, the abundance of larger phytoplankton species decreases due to a lack of nutrients while the smaller picoplankton species maintain a constant biomass by recycling the limited available nutrients within their population (Paerl et al., 2014). Since picocyanobacteria contribute about half of the primary production in the NRE, P. ovalis can possibly transfer 25% of that 50% primary productivity to higher trophic levels (Paerl et al., 2020). P. ovalis transferring organic matter that would otherwise be inaccessible to larger species such as copepods is crucial because the cyanobacteria are too small in size to be consumed by the larger predators (Berggreen et al., 1988). I hope these estimates of grazing potential by P. ovalis will motivate future studies to further assess the ecological role of P. ovalis by directly measuring its grazing rate and the rate of P. ovalis consumption by higher trophic levels.

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About the Author

Luke Townsend is a senior studying marine and environmental science at the University of North Carolina at Chapel Hill with hopes of conducting research to help protect marine life. During his undergraduate career, Luke has worked as an undergraduate assistant in a marine science laboratory, rehabilitated injured sea turtles as an intern at the Karen Beasley Sea Turtle Rescue and Rehabilitation Center, and studied hydrology and water rights on the Galapagos Islands as part of a UNC study-abroad program. Recently, Luke completed a capstone project and started his honors thesis at UNC's Institute of Marine Sciences (IMS). Through the UNC-IMS program, Luke is conducting original research on the testate rhizopod, Paulinella ovalis, to determine its ecological role in the microbial food web by measuring its growth rate and examining its spatial and seasonal distribution in the Neuse River Estuarine system. Through this incredible experience, Luke has gained a greater appreciation of marine life and hopes to continue his dream of protecting marine life through future research efforts.

Contributors of Diarrheal Disease in Bokaro, Jharkhand, India

by Mehal Churiwal*, Annika Alicardi, Hannah Feinsilber, Lauren McCormick, Naijha Nsehti

Diarrhea is a major public health challenge in India due to inadequate water and sanitation, malnutrition, and a confluence of social and economic factors. Health professionals in the Bokaro district of Jharkhand, a state in northeastern India, reported high levels of diarrhea in their area to our research team. A 2016 study found that diarrheal diseases were the most significant contributor to years of life lost from premature mortality in Jharkhand, supporting the reports from Bokaro. Our team conducted a research project to characterize the burden of diarrhea in Bokaro and the local- and community-level factors contributing to it. Fieldwork consisted of eight focus groups plus interviews with 22 community members and 12 healthcare professionals. Study areas included urban commercial, urban slum, and rural communities in the Chas and Chandankiyari blocks of Bokaro. Perceptions of diarrhea prevalence were highly variable in our study population; health professionals expressed greater concern than community members. Those differences are partly explained by disparate understandings of what is meant by the term "diarrhea." For example, community members often accepted multiple loose bowel movements per day as normal, whereas health professionals recognized them as characteristic of diarrhea. We also found that community members reported potable water, functional sanitation systems, and personal hygiene resources being less accessible than government officials claimed. These inconsistencies, alongside ineffective communication between residents and professionals, pose a serious challenge to accurately assessing the prevalence of diarrhea in the area, determining its possible sources, and developing effective mitigation strategies.

Keywords: CHAS, CHANDANKIYARI, BOKARO, JHARKHAND, INDIA, DIARRHEA, WATER, SANITATION, HYGIENE

INTRODUCTION

Although the worldwide rate of diarrhea has steadily declined over the last several decades, the global burden of diarrheal disease remains high. In 2010 alone, there were an estimated 1.73 billion episodes of diarrhea in children under 5 years of age, of which approximately 36 million progressed to severe cases, and 700,000 ultimately led to death [1]. This diarrhea-related morbidity and mortality is particularly prevalent in low- and middle-income countries where inadequate water and sanitation, undernutrition, and a confluence ofIn India, the overall prevalence of diarrhea between 2002 and 2013 was estimated to be 22%, with malnutrition, anemia, and low socioeconomic status acting as significant risk factors [2]. In the northeastern state of Jharkhand, specifically, a 2016 study found that diarrheal diseases are the most significant contributor to years of life lost due to premature mortality [3]. Jharkhand is the second-poorest state in India, with a substantial proportion of the population living below the poverty line. It is characterized by classic indicators of poor healthcare infrastructure, including high infant and maternal mortality rates, a high infectious disease burden, low childhood immunization rates, and irregular access to health services [4].

socioeconomic factors create favorable conditions for diarrhea outbreaks.

In India, the overall prevalence of diarrhea between 2002 and 2013 was estimated to be 22%, with malnutrition, anemia, and low

socioeconomic status acting as significant risk factors [2]. In the northeastern state of Jharkhand, specifically, a 2016 study found that diarrheal diseases are the most significant contributor to years of life lost due to premature mortality [3]. Jharkhand is the second-poorest state in India, with a substantial proportion of the population living below the poverty line. It is characterized by classic indicators of poor healthcare infrastructure, including high infant and maternal mortality rates, a high infectious disease burden, low childhood immunization rates, and irregular access to health services [4].

Local health professionals in the Bokaro district of Jharkhand have expressed that diarrhea rates are unusually high in their patients due to personal hygiene practices, a lack of education in disease prevention, insufficient access to potable water, and inadequate waste disposal mechanisms. However, this information is anecdotal and, although scattered data on diarrhea rates in Bokaro exist, there has been no systematic collection nor analysis to support their opinions. To address this gap in knowledge, our team was awarded a research grant by the University of North Carolina at Chapel Hill to characterize the burden of diarrhea in Bokaro and the local- and community-level factors contributing to it. The team spent four weeks from mid-December 2019 to mid-January 2020 in the Chas and

Chandankiyari blocks of Bokaro performing fieldwork with the assistance of local contacts. This study aimed to explore the levels of diarrhea in Bokaro and the factors understood to be contributing to the transmission of diarrhea in the area from the perspective of community members and healthcare professionals.

METHODS

Our research consisted of three components—focus groups, community interviews, and health professional interviews—administered in rural, urban commercial, and urban slum communities (Table 1).

Two survey tools were developed for the focus groups: a quantitative multiple-choice questionnaire and a qualitative semi-structured questionnaire. The quantitative multiple-choice questionnaire consisted of yes-and-no questions regarding participants' socioeconomic status, water sources, defecation practices, hygiene habits, and perceptions of diarrhea. The qualitative semi-structured questionnaire focused on a similar set of topics but posited open-ended questions. These questions allowed participants to elaborate on their responses and highlight future improvements they would like to see in their communities. We developed separate instruments for interviewing individual community members and healthcare professionals. The questionnaire developed for community members paralleled the issues covered in the focus group surveys but consisted of open-ended questions to gather detailed information on a single-household basis. The questionnaire developed for healthcare professionals aimed to gain a population-level understanding of the diarrhea burden and factors contributing to it from the perspective of a local expert.

Table 1. Summary of Study Components

| | Focus Groups | Individual Interviews | |
		Community	Health Professional
Rural	6	19	5
Urban Commercial	1	0	3
Urban Slum	1*	2	3
Total	8	21	11

* This focus group began with 7 participants, but 2 individuals left due to employment commitments after 12 of 33 questions. The remaining 21 questions were only answered by the other 5 participants.

All survey instruments were first developed in English, then translated into Hindi by a bilingual researcher and cross-checked by multiple bilingual contacts in the study area whose first language is Hindi. The administration protocols for each questionnaire were developed in consultation with local contacts, then tested before being finalized. We convened three trial focus groups in the local area before beginning data collection: a group of rural women participating in a female empowerment training, a group of individuals living in an urban slum, and a group of nurses working in a local hospital.

The study sites and participants interviewed for this study constituted a convenience sample. To locate participants for our rural focus groups and community interviews, we were assisted by the Jharkhand State Livelihood Promotion Society (JSLPS)*, which arranged six rural communities for our team to visit accompanied by one to three staff members who are familiar with that village. To locate participants for our urban focus groups and community interviews, we sought out communities based on the feasibility of recruiting willing participants as urban areas are limited in Chas and Chandankiyari. To locate participants for our health professional interviews, we visited all but one of the major hospitals within Chas and Chandankiyari either by accompanying staff from JSLPS or through the assistance of other contacts in the local healthcare system.

All focus groups and interviews were conducted and recorded** with the participant(s)' verbal consent. At the beginning of each focus group, a test question was administered to ensure familiarity with the response procedure. For the quantitative questionnaire, participants were asked to respond to each question by raising their hand when the correct answer choice was called out so the study team could total the number of responses. This was immediately followed by administration of the qualitative questionnaire, during which several participants took turns responding to each question. Responses

Responses were translated in real-time by local bilingual assistants, then recorded by the research team. After each focus group, up to four community members who had not participated in the focus group were asked to take part in an individual interview; if present, we requested that community leaders participate in this portion of the study due to their unique awareness of the circumstances facing the community as a whole. Members of the research team also facilitated these interviews with the assistance of local bilingual contacts as necessary. Collectively, we conducted eight focus groups with 71 community members across all sites; following seven of the eight focus groups, two to four individual interviews were conducted with a total of 22 community members.

The interviews with healthcare professionals were conducted at the site of their practice or, in one case, in their in-home office. Local bilingual contacts assisted with real-time translation as needed based on the participant's ability to speak English. In total, 11 such interviews were conducted with five private-sector physicians, three government physicians, an NGO women's health provider, a Civil Surgeon, and a retired District Management Officer.

After compiling all quantitative and qualitative responses for analysis, the data were stratified by community type to compare community members' and healthcare professionals' responses between rural participants, urban slum participants, and urban commercial participants.

RESULTS

Focus group and community interview participants mainly consisted of individuals from rural areas (Table 2). Compared to the urban commercial and urban slum participants, our rural cohort was characterized by indicators of low socioeconomic status such as having large households, houses that are partially or fully non-concrete, and minimal to no education. The responses given by community members were often diverse and dissimilar from the responses given by health professionals.

Perceptions of Diarrhea Levels & Characteristics:

When asked if anyone in their household had diarrhea in the prior year based on their own definition of the term, all urban commercial and urban slum participants said no. In rural communities, 97% of participants responded that no children in their household under age five had diarrhea in the previous year and 91% responded that no one six-years or older had diarrhea in the past year. However, when one rural focus group was asked whether they had experienced "loose motion"—a term used to describe loose stool—more than four times in a single day over the last year, the majority of participants responded affirmatively. Furthermore, when health professionals were asked to describe the burden of diarrhea in the area, 36% said diarrhea levels were high, particularly in Chandankiyari and the urban slums; 55% said cases had reduced in recent years, but diarrhea remains common primarily during monsoon season; and 9% said diarrhea levels are high, but only in specific villages.

The defining characteristics of diarrhea described by our study participants were highly variable and community members' responses differed considerably from those given by physicians and other health professionals (Table 3). Health professionals primarily focused on loose stool as the defining characteristic of diarrhea and described dehydration, vomiting, weakness, and abdominal pain as associated symptoms with varying degrees of regularity. Community members, on the other hand, most commonly presented loose stool and vomiting as the defining characteristics of diarrhea. These participants also mentioned a wide range of additional characteristics and associated symptoms, such that no "common" definition emerged.

Overall, 83% of focus group participants responded affirmatively when asked if diarrhea is a serious health concern; 15% were unsure or did not know, and just 3% did not believe diarrhea to be serious. The proportion of participants who thought diarrhea is serious was very similar across all three community types; however, the proportion of those who did not believe diarrhea to be serious, or were unsure, was more

variable (Figure 1). In describing diarrhea during open-ended focus group discussions and individual interviews, just one participant expressed the view that diarrhea is not serious by stating that the condition would not be dangerous if properly managed. By contrast, diarrhea was spontaneously referred to as serious, dangerous, concerning, lethal, or fear-inducing in two focus groups and six community interviews. For example, one interviewee stated that: "I think that if you don't get treatment, it is life-threatening."
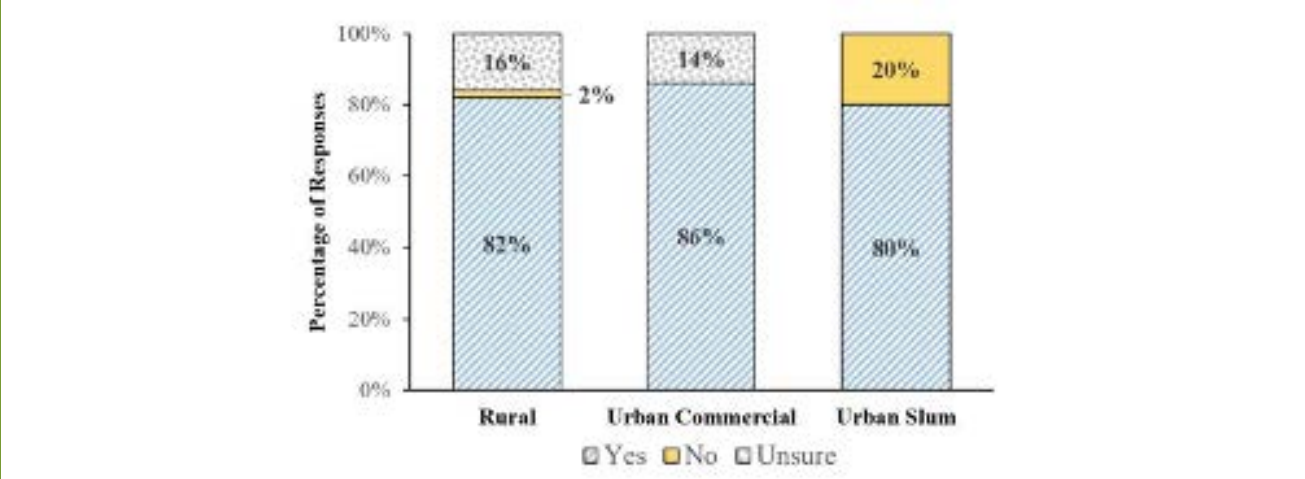
Figure 1. Focus group responses when asked "Is diarrhea serious to a person's health?"

Table 2. Description of Study Participants

Focus Groups

	Rural (%)	Urban Commercial (%)	Urban Slum (%)
Male	15 (26)	7 (100)	3 (43)
Female	42 (74)	-	4* (57)
Household Size:			
1 – 4 people	15 (26)	5 (71)	2 (29)
5 – 8 people	32 (56)	1 (14)	4 (57)
More than 8 people	10 (18)	1 (14)	1 (14)
Household roof type:			
Concrete	9 (16)	7 (100)	2 (29)
Non-concrete	21 (37)	-	5 (71)
Both	27 (47)	-	-
Highest level of education⁺:			
None	21 (54)	-	2 (29)
1ˢᵗ – 5ᵗʰ grade	2 (5)	-	1 (14)
6ᵗʰ – 10ᵗʰ grade	13 (33)	-	3 (43)
11ᵗʰ – 12ᵗʰ grade	1 (3)	-	1 (14)
College	2 (5)	7 (100)	-

Community Interviews

	Rural (%)	Urban Commercial (%)	Urban Slum (%)
Male	9 (47)	-	2 (100)
Female	10 (53)	-	-
Household size:			
1 – 4 people	3 (16)	-	-
5 – 8 people	11 (58)	-	2 (100)
More than 8 people	4 (21)	-	-
Unknown	1 (5)	-	-
Education:			
None	4 (21)	-	1 (50)
1ˢᵗ – 5ᵗʰ grade	1 (5)	-	-
6ᵗʰ – 10ᵗʰ grade	5 (26)	-	1 (50)
11ᵗʰ – 12ᵗʰ grade	4 (21)	-	-
College	2 (11)	-	-
Unknown	3 (16)	-	-
Age:			
Younger than 20	1 (5)	-	1 (50)
20 – 39 years	10 (53)	-	1 (50)
40 – 59 years	3 (16)	-	-
Older than 60	1 (5)	-	-
Unknown	4 (21)	-	-

* Two women left this focus group after 12 of 33 questions due to employment commitments.
+ This question was not asked to two of the six rural focus groups; thus, it was asked to a total of 39 rural participants.

Contributory Factors of Diarrhea:

Participants ascribed diarrhea to a broad range of causes, with the two most common being contaminated food and water (Table 3). Both community members and health professionals mentioned unclean water more frequently than unsafe food, but the difference was more significant for the health professionals. Malnutrition, poor sanitation, and living near domestic animals were all causes of diarrhea more frequently mentioned by health professionals than community members. In contrast, poor personal hygiene, mosquitos, and lack of sleep were mentioned by community members but not health professionals.

When asked to select the "most important" cause of diarrhea—given a choice between unsafe food, unclean water, and dirty hands—a plurality of respondents in the rural and urban commercial focus groups chose unclean water (Figure 2). In the urban slum focus group, by contrast, 40% selected unclean water and 40% selected unsafe food. Notably, 25% of rural participants refused to answer the question stating that they could not choose between the provided answer choices as multiple were important causes of diarrhea. Although only one participant selected dirty hands as the "most important" cause of diarrhea overall, 29% of urban commercial participants and 60% of rural participants labeled dirty hands the most important cause of diarrhea for children five-years-old or younger.

Table 3. Defining Characteristics of Diarrhea, Associated Symptoms, and Primary Causes Identified by Participants

Defining Characteristics of Diarrhea

	FGDs	Community Interviews	Health Professional Interviews
Abdominal pain	-	1	1
Dehydration	1	1	-
Loose stool	4	9	4
Vomiting	4	4	1
Weakness	-	1	-
Headache	-	1	-
Participant was unsure	-	2	-

Symptoms Associated with Diarrhea

	FGDs	Community Interviews	Health Professional Interviews
Abdominal pain	-	1	1
Blood loss	-	1	-
Dehydration	3	1	5
Fever	1	-	-
Loose stool	2	3	-
Vomiting	1	3	3
Weakness	4	2	-
Nausea	-	-	1

Identified Causes of Diarrhea

	FGDs	Community Interviews	Health Professional Interviews
Contaminated food	5	9	7
Contaminated water	5	11	11
Poor hygiene	3	6	6
Mosquitos	3	1	-
Poor sanitation	1	1	5
Malnutrition	-	1	2
Lack of sleep	-	1	-
Proximity to animals	1	1	1
Heat	-	2	-
Breastfeeding	-	1	-

The community members in this study collectively expressed a desire for substantial improvements regarding major drivers of diarrhea in the area. Still, multiple government officials interviewed expressed the belief that villagers are not sufficiently knowledgeable of these problems and, as a result, are not taking adequate action to address them. One healthcare official stated that: "If the gram sabha*** members press [for] this project, sure there is some bureaucracy…but they can press [to] make a drainage for me, make a road for me, give me safe drinking water for me, so the thing is that the gram sabha is not very active."

Water

The majority of participants in urban commercial communities (86%) obtain drinking water from the government, while the majority of those in urban slum (100%) and rural (97%) communities do not. Participants living in urban commercial communities who receive government-supplied water do so from a pipeline, while those who obtain water from non-governmental sources do so either through a hand-pump or by delivery. Rural communities obtain their non-government supplied water from hand-pumps, while urban slum communities have their water delivered (Figure 3).

All participants in rural communities (100%) and some in urban communities (40%) do not use government-supplied water for bathing; instead, these individuals primarily bathe in a local lake (rural, 77%) or use hand-pump water (urban, 100%) for such activities. All participants in urban slum communities (100%) and most in urban communities (60%) use government-supplied, piped water for bathing.

According to focus group responses, the majority of people in rural and urban slum communities do not purify their water, while those in urban commercial areas do (Figure 3). In rural areas, participants stated that the lack of gasoline or wood makes it difficult to boil water regularly. As a result, water is not typically boiled unless there is an ongoing diarrhea outbreak since boiling water is seen as a preventive measure. In one community interview, a participant explained that the government only provides gasoline to some people, yet they still encourage citizens not to cut down trees and be considerate of the environment, making it impossible for the villagers to acquire fuel. This interviewee stated that, while the village does cut down a small number of trees in defiance of the government's recommendation, it is not enough to provide for regular water purification.

In addition to a lack of purification resources, respondents—particularly in rural areas—emphasized significant challenges

with hand-pump access and water quality. The most common issues identified by participants included insufficient hand-pump availability, lack of proximity, shallow borings, poor construction, and susceptibility to drying up during the dry season. One community participant stated that, "the most difficulty in water is here. Here, if a deep boring were done for water, then no diarrhea would spread here, nothing will happen here. So for this, the government should pay attention."

Additionally, participants in the urban areas, as well as health professionals and government workers, noted that a lack of city planning has made it challenging to install drainage systems. This problem is magnified in rural areas as, according to two health professionals and one community participant, infrastructural inadequacies allow sewage to seep into the boring connected to improperly installed hand-pumps leading to contaminated drinking water. The insufficiency of hand-pumps is such that one interviewee stated community members fight over water from the pump even when functioning properly.
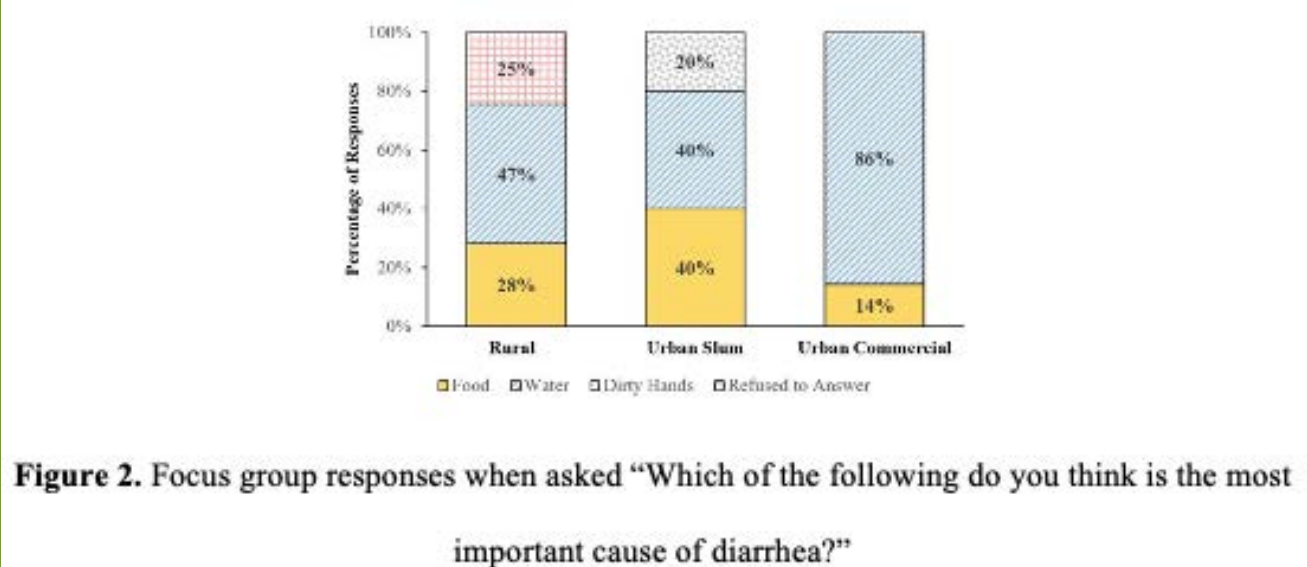
Figure 2. Focus group responses when asked "Which of the following do you think is the most important cause of diarrhea?"

Although some individuals mentioned that access to potable water has improved over the last few years, there was a consensus among healthcare providers that improvement is still needed. For example, one provider stated that "[The] government should provide healthy drinking water to all of us to improve the status of the community.... Still, everyone is using [their] own resources. [The] government is not doing central supply by plants and all that... in this locality, we [have heard for] five years that we will get water supply from [a] pipeline, but still, it is incomplete. So many hawkers are there who are getting water from different places and they are selling [to] our locality, which is not hygienic, not hygienic at all."

Sanitation and Hygiene:

Physicians and government workers mentioned that the government has been making efforts to stop open defecation for the past three to four years by providing citizens with non-flush toilets as part of the nationwide *Swachh Bharat* campaign; however, as one physician noted, "many people openly defecate, even if they have a toilet." During individual interviews, several participants reported having a toilet but continuing to openly defecate for various reasons, including convenience, the bathroom being too dirty, or the tank being too small: "Sometimes I openly defecate, sometimes I go to the toilet. There are small tanks, if I always use it, what will happen?" During another interview, a rural community member stated that she has a non-flush toilet in her home but still prefers to defecate openly because it makes her feel like a part of her community. Despite the reports of open defecation that we heard, one community interviewee stated that open defecation is no longer a problem in the area: "No, right now no one [openly defecates], it used to happen before."

Quantitative data obtained across the eight focus groups revealed that none of the participants who live in urban commercial communities openly defecate, while the majority of those living in rural communities do (61%). In the urban slum focus group, four of five participants stated that they openly defecate. None of the rural community participants said that they used a toilet that flushes, but most of those in urban commercial communities did (57%). Only one participant in the urban slum focus group reported using a toilet and indicated that it was a flush toilet. Some community participants said there is no government assistance to help them build toilets, so only wealthy people can afford to have one; others said that the government has previously provided financial support for poor individuals to build toilets.

Community members and healthcare professionals conveyed a desire to improve sanitation and cleanliness throughout their

communities, but this was especially true in the urban areas. When asked how clean they believed their street to be, all participants in the urban commercial and urban slum communities answered with "very clean" and "not clean," respectively. In the rural areas, all focus group participants considered their street to be either "very clean" (47%) or "somewhat clean" (53%) (Figure 4). However, during subsequent discussions and interviews with community members, participants in those same rural communities revealed that they did have concerns with their community's cleanliness, specifically citing a lack of sanitation and drainage systems. Additionally, healthcare professionals expressed dissatisfaction with Swachh Bharat's outcome, describing it as ineffective in achieving its goal of an open defecation-free India. They reiterated the concerns of community members and expressed a similar desire to improve sanitation and cleanliness.

According to the data from the focus groups and individual interviews, all three community types used improper handwashing techniques, partly due to soap being too expensive or difficult to find. In rural and urban slum communities, the majority of interviewees said they typically wash their hands with only mud or water. Additionally, when specifically asked whether their children wash their hands before getting water, 100% of focus group participants across all community types responded negatively.
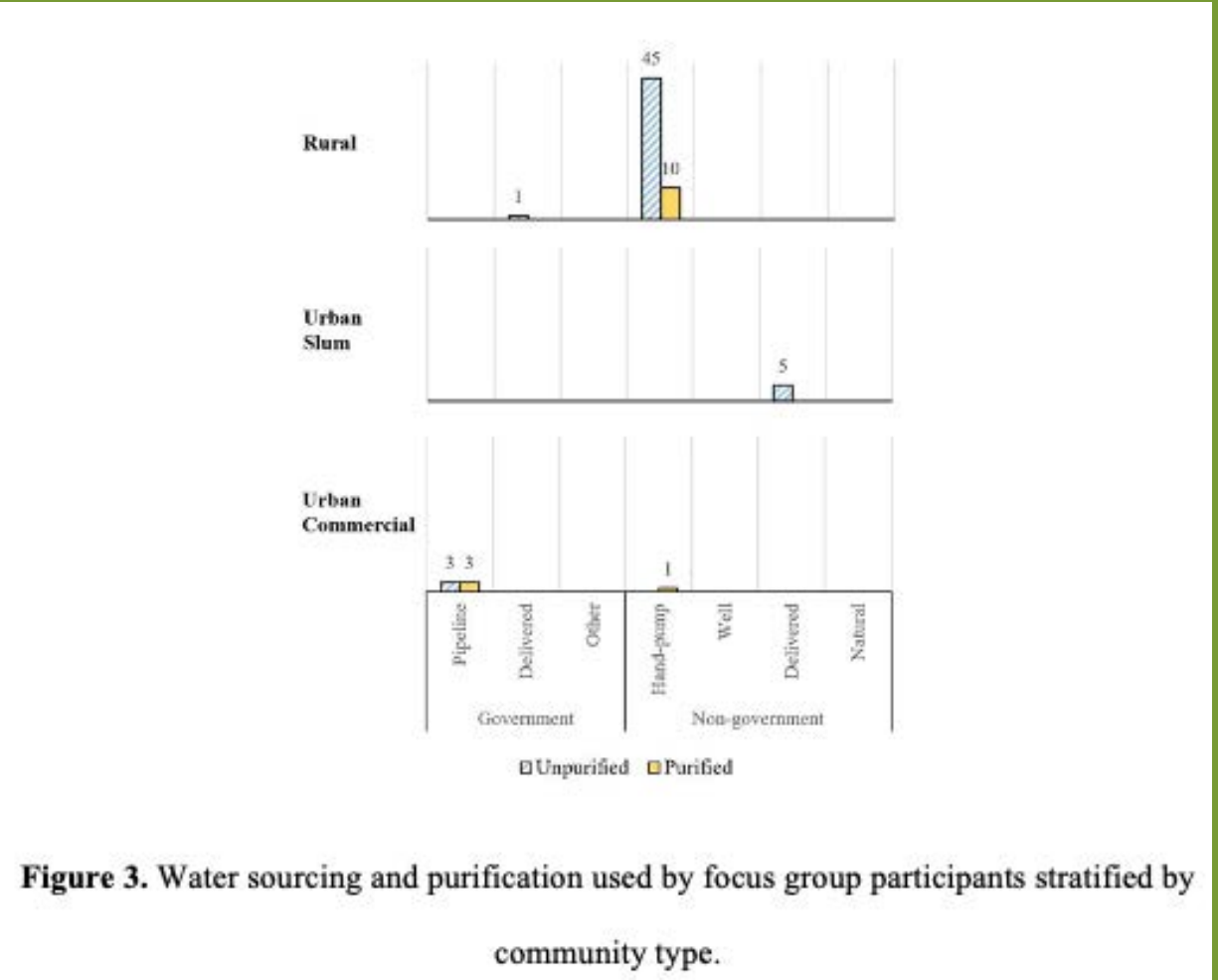
Figure 3. Water sourcing and purification used by focus group participants stratified by community type.

DISCUSSION

Community respondents without expertise in allopathic medicine or public health defined diarrhea by a highly variable set of characteristics of which loose or watery stool was the most common, but rarely mentioned independently. According to the World Health Organization, diarrhea is "the passage of three or more loose or liquid stools per day (or more frequent passage than is normal for the individual)" [5]. Thus, contrary to most community participants' understanding, diarrhea is a symptom that is medically defined by the frequency and nature of an individual's stool alone. Community respondents conceptualized diarrhea as being a disease in and of itself rather than a symptom. That is to say, respondents described diarrhea as being a state of illness in which the afflicted individual experiences loose stool accompanied by some set of additional symptoms, rather than as frequent loose stool alone.
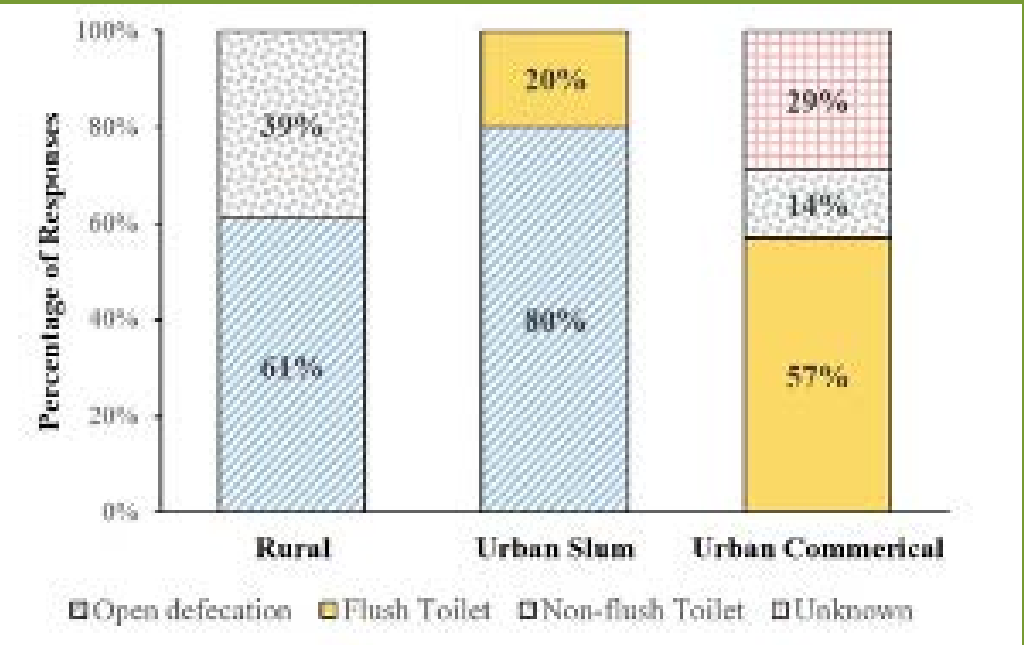
Figure 4. Defecation practices by community type

The defining characteristic most commonly associated with diarrhea by community participants, after loose motion, was vomiting. The symptomatic combination of diarrhea and vomiting represents the standard clinical presentation of viral gastroenteritis, which is most commonly caused by norovirus and rotavirus [6]. Rotavirus specifically accounts for a substantial portion of severe diarrhea cases in India, particularly for young children, according to both the health professionals interviewed for this study and prior research [7]. Thus, a substantial proportion of community participants understood diarrhea as being defined by the constellation of symptoms associated with the most well-known cause of diarrhea in the area. Overall, this study's participant responses revealed that, while diarrhea as a concept is widely understood to be a serious condition worthy of concern in the study area, the exact nature of the threat is ill-defined for many in the community.

The discordance noted between the medical and individual definitions of diarrhea in our study population could explain the discrepancy observed between the diarrhea burden recognized by community members and that described by health professionals. 98% of focus group participants stated that no children in their household under age five had diarrhea in the prior year and 93% said that no one six-years or older had diarrhea in the past year. In contrast, 91% of health professionals interviewed stated that the diarrhea burden either remains notably high in the area (36%) or has reduced in recent years but is still high during the monsoon season (55%). These differences suggest that diarrhea may be under-reported in Bokaro due to divergent interpretations of survey language.

Both the community members and health professionals interviewed expressed an understanding of the role of contaminated food and water in spreading the fecal-oral pathogens primarily responsible for diarrhea [8]. Despite that fact, significant room for improvement remains in individual and government-led strategies enacted in the study area to prevent such contamination.

One prominent example of this phenomenon highlighted in several community interviews was the state of government-installed hand-pumps across Chas and Chandankiyari. According to multiple participants, these hand-pumps were installed by the state government as part of an effort to expand access to clean water in rural areas, but they have failed to achieve the program's stated goal due to excessive distance from most houses and improper construction. One of the most common structural problems described by those interviewed was shallow borings. The ideal boring depth for a hand-pump depends on the precise hydrogeology of the installation site, but in all cases, a deeper boring allows for fewer contaminants to seep into the groundwater due to progressive filtration by permeable soil layers [9]. Shallow borings like those described by the study participants provide water contaminated by pathogens and toxic chemicals to a greater degree than deeper borings due to the decreased filtration—a problem that is exacerbated by the lack of adequate sewage and waste disposal mechanisms in most villages. Furthermore, according to the individuals interviewed, hand-pumps regularly run dry during the dry season, in part due to insufficient depth. As a result, community members resort to using natural water sources such as lakes and rivers—the same bodies of water in which they bathe themselves and their livestock, contributing to the spread of bacterial and protozoal pathogens [10].

Even if communities have sufficient access to potable water sources, water can easily be contaminated by hands, storage containers, and retrieval devices between the point of collection and the time of consumption [11]. Consequently, in-home water purification is essential to diarrhea prevention efforts. This is commonly accomplished by boiling water before consumption which eliminates most pathogens present [12]. However, the majority of participants in our focus groups and community interviews from both rural and urban slum communities stated that they do not purify their water regularly. In rural areas, participants expressed that boiling water is economically challenging because gasoline is expensive and, therefore, must be rationed. Wood serves as a potential alternative source of fuel; however, as of June 9, 2015, the Jharkhand High Court has placed a ban on tree-cutting to encourage

ecological conservation while conducting development projects [13]. The simultaneous challenges of gasoline cost and wood acquisition are a potential factor in the lack of water purification by boiling in the urban slum and rural communities interviewed.

A key source of post-supply water contamination is unclean hands as most pathogens associated with diarrhea are transmitted through the fecal-oral route; this makes handwashing an essential component of diarrhea prevention [14]. According to those interviewed, principally in rural and urban slum areas, community members often wash their hands with only water or mud due to a lack of access to soap. Notably, the government officials we interviewed did not recognize this barrier. Instead, they stated that the low prevalence of soap usage is not attributable to a widespread lack of access but rather a series of individual choices. This is especially concerning given that washing hands with soap is significantly more effective at reducing fecal bacteria than washing hands with water alone [15].

Furthermore, in light of the previous discussion regarding contaminated water, it is important to consider the consequences of handwashing under circumstances that do not provide clean water for rinsing. Previous studies have shown that handwashing with non-potable water will still reduce the amount of fecal contamination, but not enough to lower the probability of infection from hand-to-mouth contacts below 1:1000 [16]. Thus, promoting handwashing with soap and water is a necessary step in the right direction, but it cannot reach its full potential to prevent diarrhea until the larger issue of access to clean water is confronted.

The practice of open defecation is another critical driver of diarrheal diseases that has been partially, but not entirely, addressed in the study area. Open defecation facilitates the spread of the fecal-oral pathogens responsible for causing infectious diarrhea by releasing potentially infected feces into the environment, allowing the relevant bacteria, viruses, and parasites to make their way into the water supply more easily than would be possible if a latrine were used [17]. The Indian government under Prime Minister Narendra Modi sought to address the issue of open defecation in the country beginning in 2014 with the Swachh Bharat, or "Clean India," mission. This program aimed to render the country Open Defecation Free (ODF) by 2019 through the mass construction of private and community latrines, the improvement of solid waste management, and the execution of an extensive public awareness campaign [18]. The state of Jharkhand, specifically, was declared ODF by the Chief Minister, Raghubar Das, on November 15, 2018, and the Indian government currently maintains that individual household latrine (IHHL) coverage in the state is 100% [19, 20]. However, our study's data indicates that such claims do not reflect all Jharkhand residents' experiences. While some respondents did affirm that the government subsidized the construction of a latrine in their home or community, others stated that the government is not financially supporting such efforts. Thus, a number of those interviewed did not have regular access to a latrine at all. Furthermore, a subset of those who did have access to a latrine stated that they continued to practice open defecation regularly due to the latrine's insufficient capacity, its uncleanliness, or, in one case, a sense of community identity derived from the practice. This finding supports the conclusions of prior studies that have identified socioeconomic, political, and structural barriers to latrine construction and uses in India [21, 22, 23].

In addition to supporting increased access to latrines, *Swachh Bharat* also included government-facilitated education aimed at decreasing the prevalence of diarrhea via mass media campaigns, formalized schooling, and community health workers known as sahiyas. A previous study found that nationwide diarrhea rates decreased from 2007 to 2016, indicating that the government's public education efforts have helped reduce diarrhea rates; however, the study also found that diarrhea hotspots remain in the northeastern states of India [24]. In our study population, there was consensus among the community and health professionals that diarrhea rates have decreased

over the past 5 to 10 years due, in part, to increased education and diarrhea awareness. Participants speaking in official and personal capacities stated that their government's public education efforts had a positive effect on their communities' health. However, participants in all three community types agreed that the formalized schooling and sahiya-based education promised by the government require significant improvement.

CONCLUSION

Our data demonstrates that, while community members in the Chas and Chandankiyari blocks of Bokaro generally believe diarrhea to be a serious condition worthy of concern, they lack both a full comprehension of its characteristics and causes and the ability to mitigate its spread in their communities independently. The citizenry in our study area expressed a simultaneous dependence on and distrust in their government that has contributed to a lack of mutual understanding between the two parties that in turn exacerbates its underlying causes. Although we found consistent support for this claim in our data, our conclusions were limited by the study's sample size and composition. The study did not include a statistically significant number of individuals in urban commercial and urban slum areas and it was limited to a single district in a relatively poor and rural state, making it difficult to generalize our findings to a larger population.

Furthermore, because the fieldwork was conducted with the support of female self-help groups, women were in greater proportion in our rural focus groups and interviews. Additionally, our study participants did not constitute a random sample of the population given the sampling methodology. Nonetheless, our study represents a critical exploratory identification of specific barriers to reducing the burden of diarrheal diseases in Bokaro.

Future studies are needed to investigate these barriers further and elucidate their applicability in other settings. In the course of this study, we made several observations that could serve as valuable avenues for future research. Specifically, we heard concerns from a subset of participants about the consumption of unrefrigerated food during the annual Mansa Puja festival in Chandankiyari and the contamination of uncovered street food in urban areas. Additionally, although we found that water is stored in clean, covered containers in the study area, water can still be contaminated if retrieved in an unsanitary fashion. While outside the scope of this study, it would be valuable to direct future research efforts toward exploring these phenomena and the issue of food and water contamination in the area more generally to reduce the diarrhea burden further. Most importantly, the lack of mutual understanding between the government and the populace described here could be relevant in exploring a wide range of additional public health concerns as it is a potentially confounding factor in existing interventions that must be addressed for progress to be achieved. Thus, we propose a need for further, more expansive, research into this dynamic.

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Notes
*JSLPS is an organization that establishes female self-help groups (SHGs) throughout rural Jharkhand as a means of helping communities achieve financial support and stability.
**At the participants' request, two community interviews were not recorded.
***The gram sabha is the meeting villagers have to set their priorities and agendas.

ACKNOWLEDGMENTS

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Popular Science Feature
Cancer: Does the Answer Lie in the Stars?
by Pradyun Ramesh

Microgravity environments, or environments with very small gravitational forces, in space are synonymous with muscular and immune system dysfunctions in astronauts. The adverse effects of microgravity environments pose a great danger to astronauts. However, every cloud has a silver lining. Microgravity environments are now being posited as a tool in the creation of drugs in the fight against the world's second leading cause of death: cancer. This article tracks research conducted by Devika Prasanth and her team from Creighton University and examines their observations put forward in the paper titled "Microgravity Modulates Effects of Chemotherapeutic Drugs on Cancer Cell Migration." The research focuses on the effects of microgravity on cancer metastasis, a process which is responsible for 90% of cancer deaths, and which involves the spread of cancer cells from a primary site to other locations in the body. To test their hypothesis, Prasanth and her team subjected cancer cells to forty-eight hours of microgravity and compared the migratory abilities of chemotherapy-treated cells and untreated cells. Their results showed that microgravity modulates the response of cancer cells to treatment in different ways based on the chemotherapeutic drug which was used in the treatment. The article also tracks supplementary sources which agree or disagree with Prasanth's research to varying extents. However, all of these sources concur that microgravity environments can have a significant impact on the metastatic properties of cancer cells and help in the fight against cancer.

Keywords: microgravity, cancer, metastasis, chemotherapy

The year is 2067. A global crop blight and dust storms threaten humanity's future. The only way to ensure our survival is to develop a gravitational propulsion theory and propel our settlements into space. If you think this sounds a bit far-fetched, you're probably right: it's the plot of the popular science fiction movie, Interstellar. But quite akin to the plot of this movie and several other sci-fi movies, scientists are turning to space to help solve problems on Earth. In the fight against cancer, researchers are now examining microgravity conditions prevalent in space to develop more effective anti-cancer drugs.

Today, cancer is the second leading cause of death globally and accounts for around one in six deaths (WHO 2018). Metastasis, a process which involves the spread of cancer from a primary location to other locations around the body, is responsible for around 90% of deaths due to cancer (Prasanth et al. 2020). Many chemotherapeutic drugs have been successful in targeting cancer cells, but previous research has indicated that these drugs may inadvertently increase metastasis. In an attempt to find a physical system for anti-metastasis therapy, Devika Prasanth and her team of researchers from Creighton University investigated the effects of microgravity on metastasis in their report "Microgravity Modulates Effects of Chemotherapeutic Drugs on Cancer Cell Migration."

Does a microgravity environment affect the cellular functions which are responsible for metastasis? Can a microgravity environment alter the pro-metastatic effects of chemotherapeutic drugs? Can a microgravity environment itself act as a physical system for anti-metastasis treatment? Prasanth and her team sought to address these burning questions through their research. The researchers hypothesised that microgravity might change the effects of chemotherapeutic drugs on cellular functions such as migration, which are involved in metastasis. To test her hypothesis, Prasanth

.and her team sought to address these burning questions through their research. The researchers hypothesised that microgravity might change the effects of chemotherapeutic drugs on cellular functions such as migration, which are involved in metastasis. To test her hypothesis, Prasanth subjected cancer cells to forty-eight hours of microgravity and compared the migratory abilities of chemotherapy-treated cells and untreated cells.

The team of researchers used HL60 and K562 cancer cells since they are extensively used for assessing the efficacy of chemotherapeutic agents and have been used in microgravity studies. To simulate a microgravity environment, these cells were placed in a rotary cell culture system, a device which is used to grow cell clusters in microgravity. Prasanth's team tested their hypothesis using two anti-cancer drugs currently used in the treatment for breast and lung cancer: daunorubicin (Dauno) and doxorubicin (Dox). Following forty-eight hours of simulated microgravity, the cells were treated with Dox and Dauno and were allowed to migrate under chemical stimulus for a period of six hours.

To quantify migration, the researchers used a Boyden chamber consisting of polycarbonate membranes with a pore size of five micrometres. The cancer cells squeeze through the membranes and replicate metastasis in the body. After six hours, the researchers counted the number of cancer cells in the bottom plate. The results from the experiment showed that both Dauno and Dox enhanced the post-microgravity migration of cells. The enhancement observed was considerable when compared to normal gravity conditions. Furthermore, it was observed that microgravity modulates the response of cancer cells in a drug-dependent manner (Prasanth et al. 2020).

The results obtained were similar to those in a previous study performed by Jae Ho Chung and his team of researchers. In this study, the researchers exposed two different types of lung cancer cells – adenocarcinoma (A549) and squamous cell carcinoma (H1703) to microgravity for a period of thirty-six hours. The team observed that the migratory ability of the two different kinds of lung cancer cells increased after exposure to microgravity (Chung et al. 2017), Chung also noted that microgravity can have different effects on different types of cancer cells. Nevertheless, the results of Chung's experiment support the research conducted by Prasanth and her team.

The studies conducted by Prasanth and Chung highlight the need to counter the pro-metastatic effect of chemotherapeutic drugs. Researchers all around the world have taken up the call to develop anti-metastatic treatments. Recently, a study conducted by Dr. Ortiz-Otero and his team of researchers examined the efficacy of a previously developed TNF Related Apoptosis Inducing Ligand Treatment (TRAIL) therapy as a form of anti-metastasis treatment. While the research studies an alternate form of treatment to the one conducted by Prasanth and her team, it is an important step in the field of cancer research. The results of the experiment showed that the TRAIL therapy was able to kill 80% of circulating tumor cells (CTC) after chemotherapy treatment and act effectively as a form of anti-metastasis treatment (Ortiz-Otero et al. 2020).

While the results of the studies conducted by Prasanth and her team show that microgravity itself cannot produce the required anti-metastasis effect, they have significant implications for immunotherapy. Immunotherapy is a form of treatment for cancer that uses a person's immune system to fight the disease by stimulating or boosting the natural defences of our immune system. The results from the experiment show that microgravity can be used as an immunomodulator, or an agent that modulates the immune system, to create drugs which have both anticancer and anti-metastasis properties (Prasanth et al. 2020).

So where does the answer to the treatment of cancer lie? Do we look to the stars or is the answer back here on Earth? As of now, researchers don't have all the answers to our questions, but the research conducted by Prasanth and her team is a step in the right direction. Altogether, Prasanth and her team have shown that simulated microgravity has a significant impact on the metastatic process of cancer cells and further investigation may advance the field of cancer research. The experiment also paves the way for the creation of drugs which would be more effective in outer space, thus advancing mankind's dream of space exploration and colonisation. While I'm not saying that we'll wake up one day in 2067 to find ourselves on a space settlement orbiting Saturn like in Interstellar, who knows what the future holds?

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Pradyun Ramesh is a freshman at the University of North Carolina at Chapel Hill and is currently majoring in Computer Science. Although he was born in the US, he has spent most of his life in India and still has a strong connection to his Indian roots. On the academic front, he is interested in astronomy and space colonization and has won awards in the NASA Ames Space Settlement Contest and the Asian Regional Space Settlement Design Contest. His other interests include data science, machine learning and its applications in health sciences, and cancer research.

His article 'Cancer: Does the answer lie in the stars?" is a product of his interests in astronomy and cancer research. The article addresses the latest developments in the fields of cancer research and space exploration. His article explores how microgravity, the low gravity environment prevalent in space, can play a role in the creation of anti-cancer drugs. When he's not writing pop-science articles for journals, Pradyun spends most of his time binge-watching TV shows, playing sports and teaching people how to pronounce his name correctly. He hopes to meet all of you on campus after the pandemic, but only if you've learnt how to pronounce his name correctly!

The Self-Conscious Object:
Invitation to a Beheading, Pnin, & Pale Fire

by Brett Harris

Filled with nuance and layered significance, the works of Vladimir Nabokov have tantalized critics for decades with their opacity. In particular, questions of the author's spirituality, and his concept of "otherworld" have gained prominence in Nabokovian scholarship. However, even rigorous close reading only yields the slightest of evidence, as is particularly true of Vladimir Alexandrov's reading of Invitation to a Beheading in his Nabokov's Otherworld. Cognizant of the shortcomings of traditional critical lenses in this context, this project takes a different approach. Informed by Graham Harman's object-oriented ontology, this study considers the role of objects (human and non-human) in Nabokov's texts, particularly as they move through and create narrative space as self-conscious objects. With particular attention to the conflict between self-conscious objects and their realities that will form the basis of our investigation into Nabokov's works. Invitation to a Beheading will be our first stop, as we consider how Vladimir Alexandrov's concept of Nabokov's "otherworld," as it manifests in the text, might be enriched by a reading of Cincinnatus as a self-conscious object in conflict with the ruling metaphors of the work. In the latter portion of the section, we will turn to an analysis of Pnin, as well as the eponymous character's cameos in Pale Fire, and, informed by Peter Lubin's assessments of Nabokov's phrasal tmesis, apply this criticism to Nabokov's objects, approaching the possibility of an "otherworld" in communion with Nabokov's own.

Keywords: Nabokov, Literary Criticism, Object-oriented Ontology, Otherworld

Immediately preceding Chapter 1 of Nabokov's Speak Memory, in the 1989 Vintage International edition, there is a reproduction of a map (Fig. 1). Sketched by Nabokov himself, the map details the location of the Vyra, Rozhestveno, and Batovo estates, in addition to several other landmarks and throughways. Perhaps intended to orient the reader in the geographies of Nabokov's youth, there is, however, something particularly disorienting about the sketch: namely, that it is oriented upside down. Despite this directional disruption, the map seems to function as it should. The descriptive text is all oriented in what might be considered a "conventional" way, and the different indicators of transportation or topography are fairly legible.

While the elements of this piece function as a map, there remains an immense tension within the work—specifically, that between the butterfly in the southeast corner, and the remainder of the work. Here, Nabokov's butterfly is a self-conscious object. It is simultaneously as real as the text it inhabits, and somehow more real. Despite being comprised of the same lines and pigments that create the map, the attention to detail that it evidences is lacking elsewhere in the piece. Furthermore, the butterfly confuses the map—standing in for an absent compass rose, it suggests that the space's cardinal directions are perhaps oriented to an understanding of space that challenges—or overpowers—convention. Similarly, the scale of the drawing, according to the map's conversion suggests that the butterfly cannot be real, as it would occupy an area of nearly 6

verst [2], yet again its appearance, relative to the minimal elements of the rest of the map, imply that it is the most real. Like the butterfly in whose pursuit Nabokov seemingly breaks free of space and time [1], this butterfly out of place calls us to question—what space are we coming into and, by our reading, being asked to create?

It is this conflict between self-conscious objects and their realities that will form the basis of our investigation into Nabokov's works. *Invitation to a Beheading* will be our first stop, as we consider how Vladimir Alexandrov's concept of Nabokov's "otherworld," as it manifests in the text, might be enriched by a reading of Cincinnatus' as a self-conscious object in conflict with the ruling metaphors of the work. In the latter portion of the section, we will turn to an analysis of *Pnin*, as well as the eponymous character's cameos in *Pale Fire*, and, informed by Peter Lubin's assessments of Nabokov's phrasal tmesis, apply this criticism to Nabokov's objects, approaching the possibility of an "otherworld" in communion with Nabokov's own.
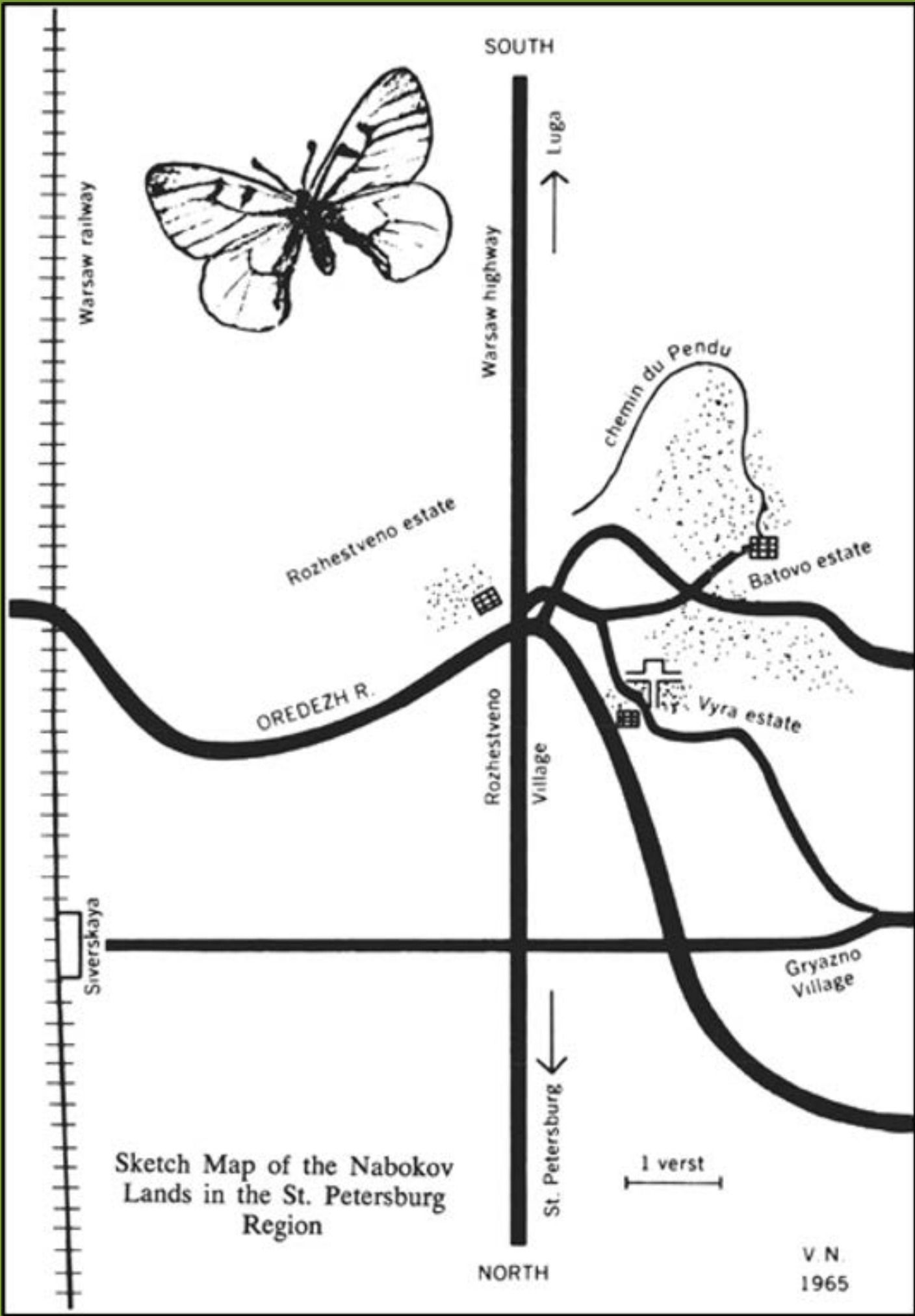
Figure 1: *Sketch Map of the Nabokov Lands in the St. Petersburg Region, Vladimir Nabokov, 1965*

Invitation to a Beheading: The Disorienting Metaphor

Drawing from Vera Nabokov's insistence on her husband's preoccupation with the possibility of modes of existence outside our own, as well as similar statements from the author's discursive works, [2] Vladimir Alexandrov's Nabokov's Otherworld traces this theme throughout several of Nabokov's major works. In particular, Alexandrov's analysis of Invitation to a Beheading provides a valuable departure point for our own investigation of the work.

Citing the work's multiple layers of significance as evidence, Alexandrov characterizes Invitation to a Beheading as "underlain by a quasi-Gnostic, dualistic world view." [3] The most apparent instance of said motifs comes in the form of "the implied duality of body and soul" [4] that follows from the scene of Cincinnatus' beheading, an episode which Alexandrov reads as a separation of body and spirit. Based on the reactions of the crowd, Alexandrov infers that Cincinnatus' beheading did in fact take place, and that the following actions are undertaken by Cincinnatus' spiritual double. Alexandrov also takes Cincinnatus' interactions with the fictive text Quercus as evidence of the work's Gnostic underpinnings. A work of literature which recounts the existence of an ancient oak tree and its surroundings, Quercus is also an object which draws the reality of Cincinnatus' plane of existence into question, as it seemingly manifests an acorn into being. Alexandrov's reading of this episode finds parallels between this interaction and a Gnostic "coded sign or a 'call' sent by the hidden deity to a select individual to awaken in him the desire to escape the earthly prison." [5]

While the majority of Alexandrov's reading focuses on these Gnostic elements of the text, he also points out several deviations from the doctrine. Most importantly, Alexandrov notes the existence of hierarchies and gradients of good or perfection in the text. Given the imperfections of the world Cincinnatus inhabits, Alexandrov argues, the ruling deity would be equated with the narrator, a device which Nabokov, clearly employs, fracturing the Gnostic doctrine of dualism. [6] Similarly drawing attention to the performative nature of the work, "the most widespread and obvious form of ... [which] is based on an extensive elaboration of the metaphor that all the world

is a stage," [7] Alexandrov notes a gradient of success in terms of the characters' performance, in addition to several layers of artifice and performance, which conflict with the absolutism of Gnosticism. Alexandrov further tempers his reading, suggesting that Nabokov's adherence to Gnostic doctrine is imperfect, and ultimately deciding that "in the final analysis, we have to return to the obvious point that although Nabokov may have used Gnostic motifs when it suited him, he did not follow an archaic religious doctrine slavishly." [8]

...

Where Alexandrov's reading falls short of an exhaustive interpretation of the text's relationship to "otherworld," it does provide an outstanding roadmap for our own analysis. Beginning with the concept of a self-conscious object—in this case, Cincinnatus himself—we will consider the object's interactions with the central, or orienting, metaphor of the work itself, as well as the implications of these interactions. Going further, this analysis questions the role of the textual object in maintaining—and deconstructing—the separation between world and otherworld. Finally, we will interrogate the events of Cincinnatus' supposed execution, coming to the conclusion that Cincinnatus' access to the otherworld is not the result of any change to his object, but to the metaphor that orients him.

Guided by Alexandrov's observation of the metaphor of the stage, our analysis begins with an examination of the work's central metaphor—the device which sets the stage of the work and populates the assumptions and ethos that (*should*) govern the characters and plot. In this case, as with *The Metamorphosis*, the clue lies in the opening line: "In accordance with the law the death sentence was announced to Cincinnatus C. in a whisper." [9] With this simple pronouncement, the text prompts the reader to create a tome's worth of conditions. For example, that Cincinnatus C. is guilty of some crime—is in conflict with the law. Furthermore, the reach of the law is likewise announced: it dictates even the volume at which the crucial proclamation is conferred. Here, the law is the central metaphor of the text—the conditions created that orient both the reader and the objects they create within them, much like the lines and notations of Nabokov's sketch in Speak Memory are unified under the concept that the object is a map. Throughout the remainder of Invitation to a Beheading, it is ultimately the law, the characters' adherence to—and deviations from—it, that motivate the text.

Moreover, like Nabokov's map, locating the central metaphor of the text allows the reader to uncover those self-conscious objects that are in conflict with it. In addition to the initial inference of the text—that Cincinnatus has committed a capital offence—instances of his indifference to the law abound, the next earliest (and most sustained) being his insistence on knowing the exact timing of his death. [10] Delving into the source of this conflict, Cincinnatus' original crime, the situation only becomes more unclear, drawing further attention to the metaphor's performance. Recounting Cincinnatus' early childhood, the narrator describes:

From his earliest years Cincinnatus... carefully managed to conceal a certain peculiarity. He was impervious to the rays of others, and therefore produced when off his guard a bizarre impression, as of a lone dark obstacle in this world of souls transparent to one another. [11]

While Cincinnatus' curious condition might provide pages of fruitful discussion concerning the qualities of objects, what is most relevant here are the implications of Cincinnatus' opacity. Up to this point in the text, Cincinnatus' world, though embracing a particular blend of magical realism, has been fairly legible, if not wholly realistic: although we cannot be quite sure of the degree to which Cincinnatus' nighttime sojourn past the confines of his cell is a figurative or literal exercise, either action seems plausible (if not wholly legal) in the universe the central metaphor constructs. [12] In contrast, Cincinnatus' crime—being opaque to other objects in the world—holds nearly no meaning at all. The narrator fails to articulate the valence of this transgression, i.e., whether the flaw lies in Cincinnatus' physical appearance, as the above quotation suggests, or in some shortcoming of performance or character. As a result, the central metaphor suffers—should Cincinnatus' physical being

prove the issue, the reality of the text is jarred. Likewise, the crime of possessing a withdrawn interior is nearly as incomprehensible. Left with an unrecognizable mode of existence on one side, and an illegible orienting law on the other, the reader is forced to consider which is more real: Cincinnatus, or the law that condemns him-- and the entire world that it creates.

As the orienting metaphor or object of the law is thrown into question, the reality of the text itself becomes suspect, a reading supported by early and frequent allusions to existence *outside* of the text. Beginning in the first chapter, the narrator identifies themself as aware of the reader's experience of the text, describing "the right-hand, still untasted part of the novel, which, during our delectable reading, we would lightly feel, mechanically testing whether there were still plenty left (and our fingers were always gladdened by the placid faithful thickness)." [13] Here, the narrator draws attention to the action of reading, prompting a reflexive consciousness of the separation of the text from the context in which the reader experiences it. Furthermore, this parenthetical portion of this aside is the continuation of a trend that further complicates the division between the textual and real. While these parentheticals are often reserved for wry qualifiers to some previous statement of action, they also carve out a space for the narrator *between* the world of Cincinnatus and our own. The most curious of these occurs as Cincinnatus is being escorted from his cell: "'But we don't have to go this very minute, do we?' asked Cincinnatus, and was himself surprised at what he was saying, 'I haven't quite prepared myself...' (Cincinnatus is that you speaking?)." [14] Although this moment may be read as just another wry indicator of Cincinnatus' tone or manner of address, the narrator's direct address, in addition to the breakdown of the performance—and eventually, the world—as precipitated by the moth's arrival, [15] it also suggests a similar deconstruction, or permeability of the barriers between the text, the narrator, and the reader. Just as the reader encounters the narrator's voice, so too can the narrator hear Cincinnatus—and further, they believe that Cincinnatus can hear them.

In addition to the narrator's seeming occupation of a space between texts, other instances in the novel suggest the ability of objects to travel between them. In particular, the novel Quercus blurs the line between textual and real within Invitation to a Beheading. A work concerned not only with the events surrounding the fictitious tree, Quercus is also written in such a manner that it attempts to create an exhaustive portrait of the tree's existence, "filled with scientific descriptions of the oak itself, from the viewpoints of dendrology, ornithology, coleopterology, mythology, or popular descriptions, with touches of folk humor." [16] Here, the eponymous object which Quercus creates provides a foil to Cincinnatus: the subject of this invented novel, despite all the author's descriptions—and prescriptions-- of it and its context, remains inexhaustible to the reader's experience. Similarly, just as Cincinnatus is later able to travel between levels of textuality, a trait shared by the narrator, so too does the Quercus manifest outside of its own text, producing "a leafy breeze" and "dense shadows up above," from which "fell and bounced on the blanket a large dummy acorn, twice as large as life, splendidly painted a glossy buff, and fitting its cork cup as snugly as an egg." [17] In this instance, the acorn, like Cincinnatus, is a self-conscious object. Its unrealistic size and viscerally tactile qualities are unlike anything the reader has previously encountered in the text of Invitation to a Beheading, instead offering a glimpse of existence as informed by a different pocket of reality.

Following the strand of movement between texts, we turn now to the scene of Cincinnatus' execution. Following his journey form the prison to the block, the world around Cincinnatus begins to deteriorate, beginning with the cell, which "no longer needed, was quite obviously disintegrating," [18] and by the end of the chapter "was no longer there." These moments leading up to Cincinnatus' execution suggest that the world of *Invitation to a Beheading* actually only exists so long as Cincinnatus gives meaning to it—the reason for the cell's existence is a "need" on the part of Cincinnatus. Similarly, at the moment of Cincinnatus' execution, he stands and is berated by Roman, who continues to shrink and fall away with the rest of the world as Cincinnatus disregards him. [19] In essence, the world created by the central metaphor—the law—requires the adherence of objects to its rules. Here, Cincinnatus, as a self-conscious object,

warps the text depending on his adherence to the law.

More explicitly, the self-conscious object retains the ability to re-orient its text, depending on the qualities it performs. In the case of Cincinnatus, the queering quality, as it were, is his criminality—a trait that echoes elsewhere in the text. Of Cincinnatus' lineage, the reader is informed that Cincinnatus is "the son of an unknown transient." [20] As the scale of the novel's world is unclear, and given the intertextual transit of multiple objects within the text, this "transience" suggests a precedent for Cincinnatus' own movement. Cincinnatus' mother's admission provides further evidence for such a connection: "it's true, I don't know who he was—a tramp, a fugitive, anything is possible...Oh, why can't you understand?... He was also like you, Cincinnatus." [21] Here, in addition to mirroring Cincinnatus' crime of opacity, the possibility of "fugitive" implies a similar failure to perform the prescriptions of the law. Likewise, the caveat that "anything is possible," in addition to the intertextual understanding of transience, suggests that the father—like Cincinnatus—also performs self-consciously, creating conflict with his surrounding depending on the nature of the text he inhabits. Moreover, this reading resonates with the ending of the text, in which "Cincinnatus made his way in that direction where, to judge by the voices, stood beings akin to him," [22] suggesting a bond or relationship through shared experience, and possibly ancestry, given the use of "akin."

In combination with the multiple layers of text, the ability of other objects in the text to cross between them, and our knowledge of Cincinnatus' own father, this "kinship" indicates a continuity within the text. The object of Cincinnatus did not "escape" or "transcend" the text—quite the contrary. Because the occupants of this new realm are in some way related to Cincinnatus, and given their occurrence within the text of Invitation to a Beheading, it would seem rather that he has merely entered a different pocket of the text, one in which he "fits" without performance. Paired with the dissolution of the world governed by the law that demands Cincinnatus' execution, we might read this ending not as Cincinnatus' death, but as the beheading of a metaphor hostile to his own existence.

Pnin and Pale Fire: Re-orienting the Object

Having explored briefly the means by which Nabokov's self-conscious objects traverse textual space, often alluding to and inhabiting extratextual layers of a work, we conclude this portion of our analysis with an examination of what is perhaps the most extreme example of this form of "otherworld": Pnin's exodus from his own eponymous novel into *Pale Fire*. Grounded in Peter Lubin's analysis of Nabokov's phrasal tmesis, we will consider how Nabokov uses a similar technique in creating his self-conscious objects—both human and nonhuman. From there, we will examine the role this expansion plays in the object's ability to enter into and create lacunae in the text, ultimately arriving at the conclusion that these objects, beyond the ability to re-orient themselves within a text, are further able to re-orient the text they inhabit.

Cataloging Nabokov's various linguistic feats, Stanley Lubin's "Kickshaws and motley" introduces a concept vital to understanding Nabokov's self-conscious objects. Noting the author's tendency to "fill troublesome chinks," or the "lexical lacunae" of his readers, Lubin goes on to assert that Nabokov's wordplay uncovers a sense of "magic discovered in the dun mundane." [23] Tracing this transformative effect, Lubin identifies a Nabokovian trait of "phrasal tmesis" in which "an expression... is ruptured by an alien verbal insertion." [24] As a result, the reader "apprehends the terminal words which it expects to find juxtaposed, and then must accommodate the alien phonemes thrust between." [25]In effect, Lubin argues, Nabokov takes known quantities, and imposes qualifiers upon them, disrupting the normal performance of the phrase. Thus, the performance of "enchanted hunter" is slightly thrown off when encountered as "an enchanted and very tight hunter." [26]

Moving to a more macroscopic analysis, we find similar qualifying interruptions throughout Nabokov's texts in the form of lacunae. For example, in Pnin, a description of Pnin's socks

triggers a brief history of his educational endeavors, bookended by his "almost feminine feet" and the "tremendous bare stretch of [his] shin." [27] Similarly, the cyclical structure of *Pnin*, as an anecdote related by the author as he hears it from the head of the English department, creates a similar effect: *Pnin* as told by Cockerell is simply a cruel joke, but with Nabokov's narratorial intervention, the novel—and Pnin himself—is transformed into a satire of American academia, and a poignant portrait of a beloved friend. [28] As a result, the reader must return to the text, reconciling its content with its modes of transmission, filling in the gaps created by its narrators. Nabokov takes this effect to even greater extremes in *Pale Fire*, treating the reader to a novel of lacunae—hundreds of narrative tidbits both warp and are constrained by the poem containing them.

This tension between the object as a unified whole and the object as a vessel for hidden meaning is the basis for Nabokov's self-conscious objects. For example, when Pnin enters the library, he interacts with a copy of Webster's dictionary. After losing his notes in the volume, the tome is "given a slight shake, whereupon it shed a pocket comb, a Christmas card, Pnin's notes, and a gauzy wraith of tissue paper." [29] While the contents of the dictionary are mundane, they are also unexpected—creating a soft joy, a wonder, at the carelessness of the university's denizens. Even more wondrous, immediately following the evacuation of the dictionary's contents, "Pnin pocketed his index card and, while doing so, recalled without any prompting what he had not been able to recall a while ago: ... plïla i pela, pela i plïla..." [30] Here, it would seem that, along with the combs and Christmas cards, Webster has also shed a memory, triggered by the object's physical upset. In positioning his objects in such a manner, just on the edge between real and extraordinary, Nabokov cultivates quietly self-conscious objects. Particularly in Pnin, these are never gregarious enough to shatter the reality created by the rest of the text, but enough to lend a certain whimsy and alternative understanding of the space the objects inhabit.

Turning now to the object of Pnin, his presence in both *Pnin* and *Pale Fire* creates a similar tension, demanding a careful consideration of the circumstances governing the reality of each text. Foremost, Pnin, unlike Cincinnatus, is self-conscious in a way extremely legible to most contemporary readers—he is an émigré, caught between the world of his native Russia, and that of a post-war America. Pnin, like his friends, who mistake poison-ivy for floral filler, is disoriented by his attachment to Russia, a fact which he openly discusses with a friend,

'You will lose it some day,' [Chateau] added, pointing to the Greek Catholic cross on a golden chainlet that Pnin had removed from his neck and hung on a twig. Its glint perplexed a cruising dragonfly.

'Perhaps I would not mind losing it,' said Pnin. 'As you well know, I wear it merely from sentimental reasons. And the sentiment is becoming burdensome. After all, there is too much of the physical about this attempt to keep a particle of one's childhood in contact with one's breast bone.' [31]

In this instance, it is apparent that Pnin's existence in the novel is governed by his identity as a Russian, and further constrained by his wish to retain that connection, even as he orients himself to a new culture and context. Although this orienting burden is sometimes prohibitive, as in Pnin's inability to derive pleasure from—or even comprehend—American comic strips, [32] it also grants him power over the narrative and its space. Pnin's presence at the Castle is enough to transform the New York estate into a revenant of a Russian lawn party, and his speech for the women's club is enough to summon cheerful spectres, whose presence in reality the narrator does nothing to detract from, only noting that they comprise "a brief vision." [33]

By his presence, Pnin warps the text, a fact that is evidenced both by his evacuation of Pnin and his presence in Pale Fire. Beginning with the former, it is Pnin's rebellion and departure that catalyzes the decomposition of the narrator's credibility. Left alone without the presence of his subject, the narrator is forced to turn his attention to the only other character present, Cockerell, who reveals the irony of the text: that it is being told (and edited) by an unfriendly colleague. [34] Just as with Cincinnatus' failure to preform the prescripts of the law, Pnin's refusal to continue the participate in the narratorial Nabokov's satire effectively implodes the narrative. In Pale Fire, Pnin plays a similar role. Moving through the text ordinally, [35] we first

encounter Kinbote's description of Pnin as "the head of the bloated Russian Department...a regular martinet in regard to his underlings (happily, Professor Botkin... was not subordinated to that grotesque "perfectionist")." [36] We later find him in a footnote attending a dinner party, and then, finally, in "a circular room where a bald-headed suntanned professor in a Hawaiian shirt sat at a round table reading with an ironic expression on his face a Russian book." [37] At a first glance, this change of fortunes for Pnin indicates a re-orientation of his object. No longer is he ruled by an attachment to his lost homeland, but rather, he controls the narrative of Russia as it manifests in his department. Even more telling, Pnin's presence in the text—particularly in the latter instance, observing the final stages of the assassin Gradus' hunt for Kinbote—qualifies the reality of Kinbote's tale. Because Pnin's world so easily maps onto Nabokov's own, his presence in Kinbote's narrative—particularly with his "ironic smile" suggests that Kinbote's yarn is false, a fabrication. Likewise, Pnin's success outside his original text, in which he suffered at the hands of an unkind narrator, in addition to his superior position in a Russian department fluch with funding, suggests that Pnin is finally in control of his narrative, to the detriment of Kinbote's own credibility.

...

In granting Pnin such a privileged position in *Pale Fire*, as with Cincinnatus' ability to re-orient his narrative to a more benevolent metaphor, Nabokov's treatment of self-conscious objects in his texts points to a concept of otherworld concurrent and in communication with our own. Just as Pnin is able to exert control over his narrative(s) by re-orienting himself in American society, carrying the conditions of his reality with him, the choice of orienting object likewise seems to be vital to Nabokov's metaphysics. Given his well-documented disdain for conventions of time and space, and his careful scrutiny of the parallels between his own life and the textual, [38] it would seem that, for Nabokov, the otherworld exists in those lacunae encountered in the everyday. Whether through the serendipity of a finding a memory fallen from a book, or re-orienting life to fit one's mode of existence, Nabokov's treatment of his objects gestures to the wonder inherent in having limbs in multiple perceptions of reality, "where there [is] simply no saying what miracle might happen." [39]

Footnotes
[1] Nabokov, Vladimir. Speak Memory: An Autobiography Revisited, pp. 138-9
[2] Alexandrov, Vladimir E. Nabokov's Otherworld, pp. 3-4
[3] Ibid. p. 8
[4] Ibid. p. 86
[5] Ibid. 101
[6] Ibid. p. 88
[7] Ibid. p. 90
[8] Ibid. p. 88
[9] Nabokov, Vladimir. Invitation to a Beheading, p. 9
[10] Ibid. p. 14
[11] Ibid. pp. 20-21
[12] Ibid. pp. 14-16
[13] Ibid. p. 10
[14] Ibid. p. 192
[15] Ibid. pp. 187-191—arrival of the moth
[16] Ibid. p. 112
[17] Ibid. p. 114
[18] Ibid. pp. 195-196
[19] Ibid. pp.207-208
[20] Ibid. p. 20
[21] Ibid. pp. 120-121
[22] Ibid. p. 208
[23] Lubin, Peter. "Kickshaws and Motley," p. 191
[24] Ibid. p. 194
[25] Ibid. p. 196
[26] Ibid. p. 195, Nabokov, Vladimir. The Annotated Lolita, p. 294
[27] Nabokov, Vladimir, Pnin, pp.7-9
[28] Ibid.191
[29] Ibid. p. 78

[30] Ibid. p. 79
[31] Ibid. p. 120, Poison Ivy, p. 128-Greek Catholic cross
[32] Ibid. p. 60
[33] Ibid. pp. 132-133- garden party, p. 27 brief vision
[34] Ibid. p 191
[35] Not chronologically!
[36] Nabokov, Vladimir. Pale Fire, p. 155
[37] Ibid. p. 229, p. 282
[38] Nabokov, Vladimir. Speak Memory: An Autobiography Revisited, p. 20
[39] Pnin 119

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Apostle of Post-Impressionism:
Virginia Woolf and the British Embrace of the French Avant-Garde

by Reanna Brooks

Introduction: The Beginnings of British Post-Impressionism

"The mind of an artist, in order to achieve the prodigious effort of freeing whole and entire the work that is in him, must be incandescent... there must be no obstacle in it, no foreign matter unconsumed" –Virginia Woolf

London, 1910. A classically bleak British scene. Georgian architecture suspended under dark gray skies. Frosted windows traced with droplets of rain. The narrow cobbled streets are empty except for occasional stragglers making their way swiftly against the bitter winter wind. At first glance, it appears to be an ordinary day in Mayfair. Careful examination reveals something unusual. Discarded pamphlets litter the streets, advertising some event in bold lettering. A few souls brave the English winter. Clutching their fluttering newspapers, they disappear around the corner. As the day passes, more people appear, headed in the same direction. The dreary square comes to life, and before long, a crowd has formed. The air is now warm with bodies tightly packed together, necks craning to get a glimpse around the corner. Excitement has turned to determination, desperation. At last, through a slight break in the mass, the object of so much attention is revealed: a looming building emitting light, sound, color. The immense bay windows of the building's entrance jut into the street. Bright electric light spills out of its vast windows, beckoning onlookers to warm relief from the London chill. The illustriousness inside is caught only in glimpses as people pour into the entrance, eager to see the scene (Twitchell 56). [1] The air expands with the buzzing hum of humanity as London experiences an artistic epiphany at the Grafton Galleries: The first post-impressionist exhibition. [2]

Inside, the scene is spectacular. Suspended above the British viewers, French art makes its debut. [3] Color, form, and texture seamlessly blend in the novelty of the abstract. Nothing realistic is discernable; instead paint globs overlap and definite lines are wholeheartedly omitted. The meaning of each image is conveyed by shape, hue, and symbolism rather than naturalistic technique. Never before has such an art form been attempted, and for the first time, London gazes upon the post-impressionist art giants: Cézanne, Gauguin, Manet, Matisse, Picasso, Van Gogh (Twitchell 57). As notable as the paintings are the people in attendance. Promising young representatives of the British avant-garde such as Leonard Woolf, Clive and Vanessa Bell, and Roger Fry casually linger amid the crowd. One figure stands out, weaving between the visitors in silent observation and absorption. Although slightly taller than those around her, she remains graceful and poised with her white cotton skirt swishing silently as she makes her way through the crowd. At first glance, she seems rather ordinary: dark brown hair tied loosely back in the Victorian fashion, wide-set eyes accentuating a long Roman nose. Her thin porcelain hands hang limply at her sides as she stands, observing. Only upon closer examination does her beauty reveal itself. Her demeanor is more than elegant; it's stately. Her expression is brimming with deep thought. Her eyes reveal the deepest understanding of the human condition, and behind them lies the beginnings of a new form of fiction. She stands there, unbeknownst to the others, consuming the art in order to create the next era in literature and begin a modernist movement of her own.

As an author, Woolf portrayed the truth of her perspective. As an intellect, she abided by the ideas and influences of the "Bloomsbury Group." As an artist using words, she painted vibrant landscapes and complex characters intricately woven from internal monologues and multi-perspectival narratives. Describing the peculiar nature of her consciousness in Moments of Being, she explains:

A shock is at once in my case followed by the desire to explain it. I feel that I have had a blow; but it is not, as I thought as a child, simply a blow from an enemy hidden behind the cotton wool of daily life; it is or will become a revelation of some order; it is a token of some real thing behind appearances; and I make it real by putting it into words. It is only by putting it into words that I make it whole [...]. It is the rapture I get when in writing I seem to be discovering what belongs to what; making a scene come right; making a character come together. (81)

Such was the subjectivity of Woolf. Her writings, specifically *Jacob's Room* (1922), *Mrs. Dalloway* (1924)*, To the Lighthouse* (1927)*,* and *The Waves* (1931), reflect the post impressionist movement itself, constituting a sinuous, free-flowing literary art rivaling any painting. But how did she produce this work? Some scholars argue that Woolf's first two novels fail. According to French critic Pierre-Eric Villeneuve, her earliest work "has neither grandeur nor architectural solidity [...] nor the balance of creative faculties which ensures endurance" (21). So what changed? This thesis will argue that her later, more famous works are literary attempts at post-impressionist art and fundamentally reflect the post-impressionist aesthetic.

Woolf's first two works, *The Voyage Out* and *Night and Day*, appeared in 1915 and 1919, respectively. The formal characteristics of post-impressionism were not yet adopted by British avant-gardists, and instead were written off as "either an extremely bad joke or a swindle" (Woolf *Roger Fry* 156). Furthermore, Woolf "was terrified of showing sentimentality or egotism, and of being laughed at," and only later in her career overcame these inhibitions (Lee 214). [4] The post-impressionist artists of the time had the same apprehensions. Their paralysis stemmed from "fear of failure," and they lacked "ambition to attempt those difficult and dangerous feats by which alone they could increase their resources and exercise their power by straining them to the utmost" (Woolf Roger Fry 160). Nevertheless, the elements of this art movement began penetrating society, as reflected by the positive reception of the second post impressionist exhibit in 1912, and by the success of Woolf's next novel, Jacob's Room. As Fry noted, "the pictures are the same; it is the public that has changed" (Woolf Roger Fry 153). The shift from shock in 1910 to acceptance in 1922 contributed to the increase in artists' confidence. The curator of these exhibits, Roger Fry, was derided for introducing such art to British society, yet he found the public criticism "amusing" and "amazing" (Woolf Roger Fry 157). [5] A strong emotional response, however negative, was precisely what he hoped to elicit. Fellow Bloomsbury member Desmond MacCarthy notes Fry "remained strangely calm and did not give a single damn" (Woolf Roger Fry 157).

Similarly, Woolf eventually overcame her own emotional

ulnerability to criticism and embraced her passion for literary experimentation. These exhibitions marked the turning point in Woolf's literary career, as she too observed that "human character changed," and in response altered her writing (Twitchell 56). Having learned the lessons of her mediocre first novels, Woolf burst forth as a literary titan, producing canonical works of literary modernism. Despite the range in subject matter, her writing style became solidified, iconic, and "Woolfian." Her unusual techniques of poly-subjective narrative and stream of consciousness attempted to mimic the artistic style of the post-impressionists. [6] As biographer Hermione Lee notes, "the [Friday] club's discussions, conversations with Vanessa and visits to galleries mean that Virginia was thinking a great deal about painting" (216). She was not only actively engaged with the art world, but she "treated her diary now as the equivalent of a sketch book. Now and always, she measured her work against the work of the painters, and tried to connect their language and hers" (Lee 217). Woolf herself remarks on the influence of post-impressionism on her writing, stating in a letter to Fry about his own pictures, "I felt all the elements of an absorbing novel laid before me. I could trace so many adventures and the discoveries in your pictures, apart from their beauty as pictures" (Woolf Letters IV 295). The connection between the formal aspects of post impressionism and Woolf's writing is based on the fundamental tenet of the movement: attention to the mundane. Woolf, like many of the post-impressionist artists, strove to produce profound works about the quotidian.[7] This emphasis on the mundane represented faith in the luminousness of the everyday, and argued that the ordinary contains transcendental elements, as the below painting by Maurice Denis suggests:

Maurice Dennis *Sunset in Pittsburgh 1927*

Such ordinary scenes can be extraordinary when portrayed from a different perspective. By transforming Pittsburg into a fantasy landscape, Denis underscores this luminescence of the everyday and transcends expectations of daily life. Such art align with the essence of Woolf's attention to the everyday, and forms the basis of post-impressionism.

The driving force of this movement was the attempt to dispel the elitist attitude against the everyday. In the wake of his exhibition, Roger Fry said, "the attitude of the cultivated class [...] art to them was merely a social asset [...] it was them who attacked the movement most virulently" (Woolf *Roger Fry* 158). As a writer, Woolf therefore aimed to be "much more emotional, interested in life rather than beauty" (Lee 243). In this she succeeded, producing volumes of literature characterizing her family and friends and focusing on the internal profoundness of the trivial. In this regard, she can be compared to Cézanne, Matisse, and other post-impressionists whose most famous pieces are abstract still-lifes, landscapes, and portraits that similarly focus on the everyday. For example, in Woolf's Jacob's Room, the character of the blind woman could be compared to Degas' Absinthe Drinker (1875), both being nameless, ordinary, seemingly meaningless figures. However, upon further inspection, their profoundness is revealed. The blind woman,

though mentioned once in the novel, is described with such raw tragedy that she enhances the overall artistry of Jacob's Room.describes this encounter:

Long past sunset an old blind woman sat on a camp-stool with her back to the stone wall of the Union of London and Smith's Bank, clasping a brown mongrel tight in her arms and singing out loud, not for coppers, no, from the depths of her gay and wild heart—her sinful, tanned heart—for the child who fetches her is the fruit of sin, and should have been in bed, curtained, asleep, instead of hearing in the lamplight her mother's wild song, where she sits against the Bank, singing not for coppers, with her dog against her breast. (44)

Similarly, Degas portrays his nameless couple depressingly, utilizing a color palette that evokes a tone of extreme lonesomeness and despondence. The figures are together, yet clearly deep in thought and miserable. The more anonymous and ordinary the subjects are, the more the viewers are able to relate, making this piece emotionally powerful and underscoring the profoundness in the trivial. Thus, it is not the subject matter,

Edgar Degas *The Absinthe Drinker* 1875

but the craft itself that demands recognition in its transcendence of classical realism.

I created Figure 1 below to highlight the many ways Woolf's writings overlap with the formal elements of post-impressionism: Figure 1: Venn Diagram of Relationship between Post-Impressionism and Virginia Woolf [8]
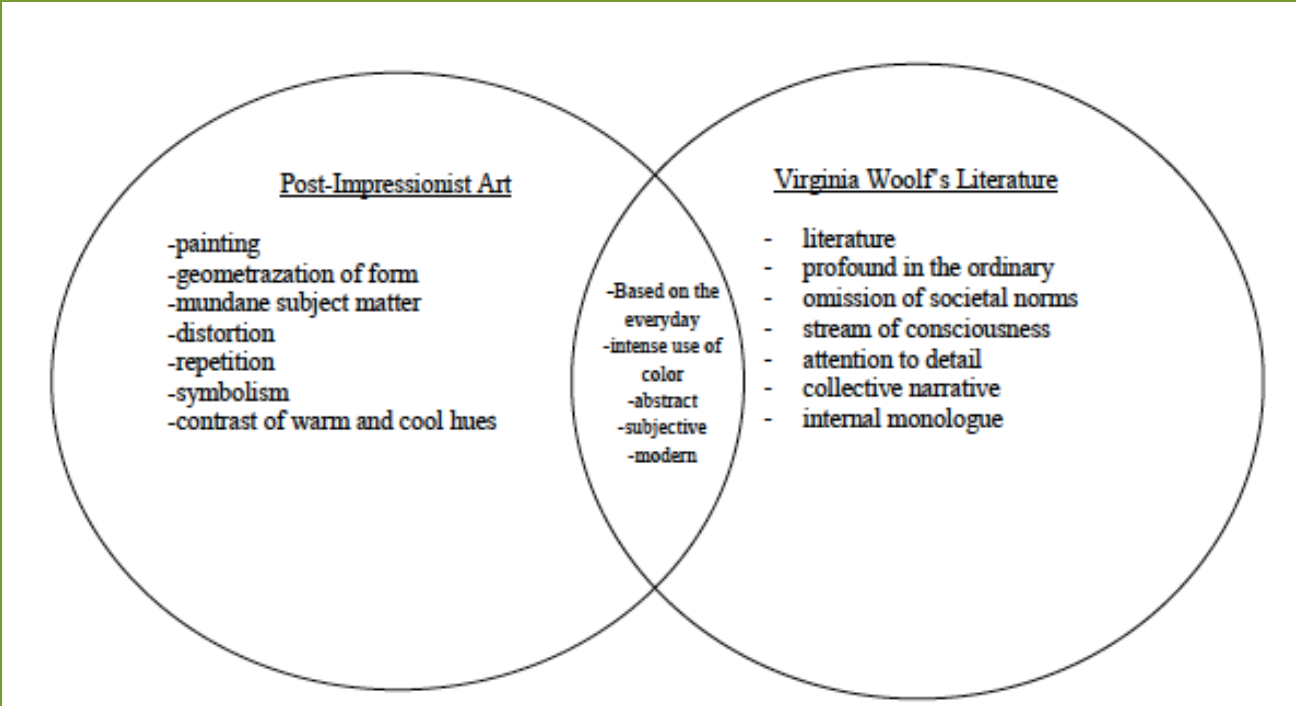
As Twitchelly summarizes, "never before had literature and the visual arts been so intricately linked, not only because of exchanges between artists, but because of similar aims" (29). Between Woolf and her inner circle, an intellectual web was crafted that trapped modernistic inspirations in its sticky fibers. Aside from the obvious intellectuals of the Bloomsbury Group, Woolf's nuclear life itself was deeply intertwined with post-impressionism and its producers. She was married to Leonard Woolf, a political and literary critic who was deeply involved with the cultivation of the post-impressionist movement in London (Woolf Roger Fry 178). [9] Her sister Vanessa Bell10 was a prominent artist who exhibited in many of the era's landmark exhibits. Roger Fry, Woolf's closest friend, not only catalyzed the movement in London but coined the term "post-impression" (Denvir 7). [11] Drawing on inspiration from gallery openings, traveling, [12] and paintings she had purchased, [13] she felt deeply connected to the art world and desired to have her own place in it. She mentions in letter to Vanessa Bell in March 1919 her wish to become an art critic for the Athenaeum, stating, "it is rather fun about the Athenaeum, as everyone is to write what they like [...] but I'd suggested that he'd much better get Duncan [14] to do the important things at any rate—not that Duncan is exactly fluent in composition, but I don't see why he and I and you shouldn't maunder about in picture galleries, and with his genius and your sublimity and my perfectly amazing gift of writing English we might turn out articles between us. Do consider this." She further expresses "amusement" and "pleasure" at French art (Woolf Letters II 341). [15] Woolf's intimate life and internal desires thus underscore the immense influence this painting-influenced period had on her and her writing.

Recognizing the foundations of the preceding impressionist and realist schools is necessary in understanding post-impressionism. Impressionism's main precursor was romanticism. Deistic in nature, this school of thought produced both authors and painters who sought communion with god through nature. The belief that one could achieve this through immersion in nature formed a painting tradition that evolved into impressionism, and eventually, post-impressionism. The impressionist inheritors of this deistic mindset believed nature was imbued with a divine spirit and reflected this idea in their works while simultaneously radicalizing these pre-existing ideas. For example, John Constable's Salisbury Cathedral from the Meadows (1831) portrays nature as mystic rather than realistic, a goal of deistic artists. In his attempt to poeticize, Constable utilizes loose brush strokes that suggest the beginnings of the impressionist technique. Moreover, his overt use of symbols highlight his attempt to convey an emotional representation of nature. As seen below, the depiction of the church and rainbow suggests traditional Christian beliefs in salvation and everlasting life, which is then strongly contrasted with the grave marker symbolizing death. Further enhancing these ideas is the heavy handed use of dark, palpable colors. Around the headstone and on the other side of the brook, Constable uses intense shades of brown, black, and dark green, and completely omits lighter tones. In contrast, around the cathedral and the rainbow he shifts his palette to light pinks, blues, and whites, essentially dividing the piece into two opposing images. Thus, Constable uses the exterior to explore the interior, suggesting how divinity exists on earth despite the debasement of society, accessible to everyone, if one only stops to look.

French post-impressionism animated the dullness of England and in doing so superseded the period of classical realism, epitomized further by artists such as Frederick Leighton (1830–1896), Edward John Poynter (1836–1919), and J.W Waterhouse (1849–1917), whose art tended to sexualize women. British post-impressionism sought to reconceive these hyper-sexualized scenes and delve deeper into the inner psyche of the viewer. The power of the paintings emerged through impassioned subjectivity instead of subject matter. The post-impressionist movement thus transcended the largely male audience of art critics and upper-class socialites, and brought art to the masses, restructuring the social hierarchy of the fine art world.

Edward John Poynter *Cave of Storm Nymphs* 1902.

At its core, post-impressionists sought to "evolve the technique" of impressionism by keeping "the accurate rendition of natural phenomena" but "transferring this realization from the conceptual to the perceptual" (Denvir 34). By adhering to a vagueness of the contemporary, this movement bolstered the idea of the subjective and sought to display the conception rather than the perception of reality. Its technique was rooted in pattern, linear rhythm, continuity, and color (Fry Henri Matisse 12).

A pivotal example is the work of Paul Cézanne, deemed the "Father of Modern Art." As demonstrated by his most famous piece, "Basket of Apples" (1895), Cézanne mastered the delicately paradoxical elements that defined this movement.

Paul Cézanne *Basket of Apples* 1895.

John Constable *Salisbury Cathedral from the Meadows* 1831.

The painting itself displays his use of constructive brushwork, which creates dimension and expressivity in an overworked still-life setting. [16] However, it's through the use of multiple perspectives that Cézanne famously created an art of the supra-spatial and supra-temporal. This piece views the apples and biscuits from different angles. The biscuits are precariously stacked while gravity spills the apples across the table, simultaneously depicting multiple viewpoints locations, and moments in time. His textured application intensifies the colors, bolstering each subject while omitting shadows and highlights that defined the prior impressionist era. He thus achieves vibrancy that transcends the confines of realism and impressionism. Through his color gradations and multiple geometric planes, Cézanne produces depth within an otherwise mundane scene, incepting the core of the post-impressionist movement. As Fry writes, these pieces "concerned the painter's insight into the nature of human emotions" (Fry "Roger Fry on Cézanne"). Their goal temporarily to subjectivize material reality forged the way for surrealism, fauvism, futurism, cubism, and other modernist movements. These experiments redefined not only the nature of art, but of humanity. Through such emotional works, the individual and the internal became the primary focus, with Fry noting that such styles are based on "equivoque and ellipsis...the dueling nature of painting" (Fry Henri Matisse 20).

Post-impressionism and Woolf's novels are plainly cognate. This thesis will consider post-impressionism's influence on Woolf's writings, and how she utilized the tenets of post impressionism to craft her own modernistic painting through words. The following chapters will respectively trace the influence of Cézanne, Matisse, and the Bloomsbury artists. Each section will explore the relationship and overlap between Woolf's writings and the post-impressionist movement, adhering to the view that she was both a modernist novelist and a post-impressionist artist.

Chapter 1: Cézanne and Woolf

"Art is a harmony parallel to nature." –Paul Cézanne

I: Background and Context of Cézanne

In a town four hundred and seventy miles south of Paris, something powerful stirs. Nestled in the rolling foothills of the Sainte-Victorie mountain, Aix-en-Provence sprawls beneath French platanes trees. Nearing the turn of the twentieth century, Aix is home to around twenty thousand, and the packed daily market on the grand boulevard seems to encompass them all. Lofty seventeenth-century Baroque architecture hovers above the scene, as merchants and buyers squeeze into the narrow streets, vying for a place in the crowd. Behind the buildings the evening sky threatens its descent in purple and pink, casting long shadows of Provencal light onto the produce below. The quickly fading light is enough, however, to catch one man's eye. He notices the enhanced vibrancy of apples spread out for sale and how their deep maroon hues seem to rival the sunset itself. This is the harmony in nature that moves him, that inspires his art. Gathering the apples, Paul Cézanne rushes home to paint one of the most influential post impressionist series of the century: still lifes of apples.

Huffing up the steep cobbled steps to his isolated studio, he pauses to catch his breath under the dominating olive tree in the center of his courtyard. He mechanically caresses its bark, deep in contemplation of the task at hand. [17] Breaking out of his trance, he readjusts himself, determined, and enters the French chateau. The click of his heels upon the tile floors reverberates through the space as he quickens his pace up the narrow staircase. Reaching the top, he bursts through the heavy wood doors creaking in protest, spilling his belongings along with himself into the studio space. All is still. Exactly as he left it. Peace and familiarity wash over him, and instinct takes over. Moving swiftly, he gathers the apples and places them on his display table, already draped in waves of white linen and tumbling onto the floor. Rearranging the turquoise and periwinkle glass bottles, he makes room for his new pomiform centerpieces. Settling himself upon his wicker chair, he observes his surroundings. Cézanne is a creature of comfort, and his studio reflects his inner content. A quick scan of the room shows "some porcelain, bottles, vases, paper or fabric flowers, fruit, apples above all, as well as skulls and the small, plaster cupid" ("Cézanne's Studio in Aix en-Provence").

These items are precious for more than sentiment's sake; they are his companions. As Cézanne explains in a letter to Joachim Gasquet:

We think that a sugar bowl has no countenance, no soul, but it changes every day...you have to know how to handle them, mollify them...those glasses, those plates, they talk to each other. These objects arouse us. A sugar bowl tells us much more about ourselves and our art as does Chardin or Monicelli. (Paul Cézanne Joachim Gasquet's Cézanne: A Memoir with Conversations)

The space itself, overflowing with silence and light, is his refuge from the world. Amid the clutter, every object has its place, and Cézanne's collection of trinkets and ornaments dutifully line the gray walls. The mismatched wooden furniture pulls the space together with haphazard shades of chestnut, mahogany, amber, and beige, echoing the worn hardwood floor. The floor-to-ceiling windows are floodgates for copious light, baking the room in an omnipresent warm glow. In every nook stands rolled canvasses, stretched and piled, awaiting their fame. Splayed easels precariously hold oversized frames, teetering dangerously as paints jostle and splash their surfaces. Rapid sketches line the walls, for inspiration, absorption, or rejection. The paint flecks of pieces past cling to every surface; reminders of previous projects and declarations of ideas. Every inch of space emits life. The life of Paul Cézanne. Such was the atmosphere in which Cézanne created his most famous pieces: *Mont Sainte-Victoires Seen from Bellevue (1886), The Basket of Apples (1895), Grandes Baigneuses (1898), and Portrait of the Gardener Vallier (1906).*

Paul Cézanne *Mont Sainte-Victoire Seen from Bellevue* 1886.

The land was Cézanne's inspiration. Residing primarily in Aix-en-Provence, he found his subjects in his immediate surroundings. Celebrated for his landscapes and still lifes, he sought to convey his "inner visions" of the nature around him (Jewell 7). In a letter to the French painter Émile Bernard, he explained, "for progress towards realization there is nothing but nature, and the eye becomes educated through contact with her" (Jewell 7). Thus he religiously painted the Aix regions, determined to paint not what he saw, but what he felt. With the style he coined "painting on the motif," Cézanne reflected the internal subjectivity of everyday objects and scenes in order to "'realize' on the basis alone of ideas generated within himself" (Jewell 6). This need to discover the motifs within his surroundings converted Cézanne into "a subjective artist" (Jewell 8). As scholar Edward Jewell explains:

Cézanne was never objective in the sense that applies to painters who try literally to set down what is before them. Cézanne always reorganized. He simplified, distorting freely when the design, for his purposes, called for distortion. He followed his innate architectonic sense, however much it might appear that he was dependent upon the object-landscape or still-life or human sitter. (Jewell 8)

This allowed him to draw "from the Provencal landscape both nature's classism and romanticism," while simultaneously forcing him to reflect upon the history of artistic styles to develop his own (Twitchell 17). In his retrospection, Cézanne "abandoned his thickly encrusted surfaces and began to address technical problems of form and color by experimenting with subtly gradated tonal variations, or 'constructive brushstrokes,' to

create dimension in his objects" (Voorhies). This made way for his trademark style: geometric planes formed by heavy brushstrokes, distorted perspectival space, and subtle gradations of color (Voorhies). Yet Cézanne did not wish to abandon the tenets of impressionism altogether. His new style built upon the past in the attempt to retain the distinct impressionist feel. He achieved this by maintaining "perfect structural organization," resulting in "every plane moving according to its newly apprehended optical principles, and yet there is no disintegration, the local color holds its own, and the *object* has its complete reality" (Fry Cèzanne 57). The incorporation of a modern technique underscored Cézanne's intention to universalize the ordinary. As Beverly Twitchell notes, "reducing natural objects to simpler, more geometric forms is one of the most obvious methods by which Cézanne...gave universality to images while purifying his technical repertoire" (Twitchell 25).

As Cézanne honed his style, whispers of his unusual technique made their way to Paris. By 1877, he had exhibited his works in numerous impressionist exhibitions, and his style was met with invariant criticism. Critics called him a "madman," suggesting he "must have delirium tremens" (Jewell 7). One art critic was deeply moved by Cézanne's works and fought for his preeminence: Roger Fry. His unwavering belief in Cézanne's brilliance helped Great Britain finally recognize him as a major historical figure. Fry challenged viewers to see Cézanne's art from a different perspective, one inspired by "a new curiosity about the contours," which "challenged the viewers" to similarly reconsider their definition of art (Twitchell 75). According to Woolf, Fry's driving desire was to ensure that "young English artists were as enthusiastic about the works of Cézanne, Matisse, and Picasso as he was...and to explain and expound the meaning of the new movement, to help the young English painters to leave the little back-water of provincial art and to take their place in the main stream" (Roger Fry 159). Due to Fry's relentless advocacy, Cézanne's works were gradually accepted. The first and second post impressionism exhibitions finally accorded Cézanne due recognition, though posthumously. Thanks to critics like Fry, "European modernism [was] brought to the British Isles and raised English interest in art...as a result of their efforts there was a turning 'away from naturalistic representation' which led to an 'artistically radical trend in English art'" (Twitchell 75). Thus began the British incarnation of the post-impressionist movement.

II: Cezanne and Color

Paul Cézanne exemplifies the post-impressionist movement. According to scholar Caroline Boyle-Tuner, post-impressionism is "the term applied to the reaction against Impressionism led by Paul Cézanne [...]" (Boyle-Turner). Although this movement was predominately French, its canons gradually won converts in Europe and Britain. Cézanne particularly inspired the British to embrace the "intellectual approach to art" (Boyle-Turner). They accepted and finally came to revere the movement. Despite the many facets of this movement, critics and artists alike agree on one point: post-impressionism represents a definitive shift in Western art. In the preface to the catalogue of the first post-impressionist exhibition, Roger Fry and Desmond MacCarthy note:

The pictures collected together in the present exhibition are the work of a group of artists `who cannot be defined by any single term. The term 'Synthetists', which has been applied to them by learned criticism, does indeed express a shared quality underlying their diversity; and it is the critical business of this introduction to expand the meaning of that word, which sounds too much like the hiss of an angry gander to be a happy appellation [...] in no school does individual temperament count for more. In fact, it is the boast of those who believe in this school, that its methods enable the individuality of the artist to find completer self-expression in his work than is possible to those who have committed themselves to representing objects more literally [...] the Post-Impressionists consider the Impressionists too naturalistic. (Boyle-Turner)

According to Fry, "Cézanne most distinctly marked the direction away from naturalism" while simultaneously "mov[ing] away from the 'complexity of the appearance of things' to the geometrical simplicity which design demands" (Boyle-Turner). Cézanne's techniques solidified the movement's fundaments. Classical painting's overworked realism does not inspire deep contemplation, an emotional vacancy to which post-impressionism responds. Such a

shift in art reception celebrated the beauty of the everyday and the individual. Art no longer relied on realistic depiction, but instead the symbolic representation of feeling and perception. Technically correct depiction of the subject matter was no longer the focus. There was instead a new, intangible center around which a single question orbited: how does this piece make you *feel?*

Both Cézanne and Woolf are notable for their use of colors. Cézanne's unusual technique of flinging "paint on a canvas in [...] a savage, undisciplined effort to create big romantic 'literary' themes of his own imaginings," coupled with his penchant for a "turbulence of lines and colors" resulted in a new and unrivalled technique (Jewell 6, Schapiro 10). Scholar Meyer Schapiro notes how Cézanne was "firmly attached" to the subjects he painted and goes on to explain the uniqueness of his artistic passions:

But the visible world is not simply represented on Cézanne's canvas. It is re-created through strokes of color among which are many that we cannot identify with an object and yet are necessary for the harmony of the whole. If his touch of pigment is a bit of nature (a tree, a fruit) and a bit of sensation (green, red), it is also an element of construction which binds sensations or objects. The whole presents itself to us on the one hand as an object-world that is colorful, varied, and harmonious, and on the other hand as the minutely ordered creation of an observant, inventive mind intensely concerned with its own process. (Schapiro 10)

Cézanne's works clearly exemplifies such forms. *View of Auvers* (1874) below expresses some of these qualities. The landscape expands outwards to the edges of the canvas; the village is surrounded by soft green rolling hills. Seclusion and isolation characterizes this village, yet not depressingly. The tone is serene and idyllic. Vibrant colors somehow encode the serene and idyllic tone. Schapiro surveys the piece's color scheme:

Its prevailing tone is a high green, unbounded, richly nuanced, and cool. The stronger touches–blue, red, and white– are small and scattered; the quantity of white, often weakly contrasted with the adjoining light colors, brightens and softens the whole [...]. The intensity of color, the degree of contrast of neighboring tones, change by tiny intervals [...] the blue roofs of the foreground coupled with the weakened reds, the bright reds of the middle distance with weakened blues and greens. Yet the span of contrast does change noticeably at certain points as we advance into depth: it is yellow against blue in the right foreground, red against green in the middle distance, green against light blue in the horizon. In the spotting of the thickly painted colors, we pass from the relative chaos of the foreground and middle ground to the clarity of the far distance. (Schapiro 44)

Paul Cezanne *View of Auvers* 1874.

By utilizing such colors, Cézanne imputes a certain "seriousness" to the landscape in order to "dramatize it for the eye" (Schapiro 9). Woolf also "dramatizes" the landscape in Jacob's Room (1922). This novel strictly adheres to color imagery that focuses every aspect of a scene, thus producing a setting with the color palette of post-impressionistic art. Rather than describing a scene, Woolf paints it. Consider the following excerpt:

The Scilly Isles were turning bluish; and suddenly blue, purple, and green flushed the sea; left it grey; struck a stripe which vanished; but when Jacob had got his shirt over his head the whole floor of the waves was blue and white, rippling and crisp, though now and again a broad purple mark appeared, like a bruise; or there floated an entire emerald tinged with yellow. He plunged. He gulped in water, spat it out, struck with his right arm, struck with his left, was towed by a rope, gasped, splashed, and was hauled on board […]

Strangely enough, you could smell violets, or if violets were impossible in July, they must grow something very pungent on the mainland then. The mainland, not so very far off– you could see the clefts in the cliffs, white cottages, smoke going up- wore an extraordinary look of calm, of sunny peace, as if wisdom and piety had descended upon the dwellers there.

But imperceptibly the cottage smoke droops, has the look of a mourning emblem, a flag floating its caress over a grave. The gulls, making their broad flight and then riding in peace, seem to mark the grave. (Woolf *Jacob's Room* 30–31)

Jacob and Timmy Durant's sailing excursion is elevated to artistic significance by Woolf's painterly writing. She crafts this scene like an artist, dabbing colors onto her metaphorical canvas in true Cézannian fashion. The result is less a description of nature than a description of a painting. Woolf applies color to every single aspect of the scene, rather than simply color characterizing one or two objects. Instead of simply stating that the isles are blue, she utilizes an everchanging color palette to bring this scene to life ("the Sicily Isles were turning bluish; and suddenly blue, purple, and green flushed the sea"), underscoring the shimmering qualities of color that constantly oscillate based on perspective. Additionally, by using cool color hues, Woolf simultaneously suggests a brooding and somber tone that's later reflected in her implications of death ("cottage smoke droops, has the looks of a mourning emblem, a flag floating its caress over a grave. The gulls […] seem to mark the grave"). Thus Woolf transcends the ordinary seascape and deepens the meaning of this scene into a retrospective on life. Expanding on the post-impressionist idea of the extraordinary within the ordinary, Woolf transforms this moment in time into a deep reflection and contemplation of death and release of the traditional self. As scholar Annette Allen remarks:

Virginia Woolf's writing is rich with such experiences. Her particular genius lies in her ability to weave these phases of mental life together in the consciousness of her characters[…]The self does not live only in its present. Its experience also consists in what is approaching it from the future and what is escaping it into the past. Or, to express Woolf's writing about these profound internal changes within the individual in relation to a context her readers understood (scenes in nature) characterized the fundaments of realism and paid homage to impressionism. However, instead of fixating only on such scenes in nature, Jacob's Room transcends mere formal experiment and utilizes the deep psychological connections associated with color as a platform for her own underlying narrative: the recent war dead. She alludes to the war by describing the cottage smoke as having "the look of a mourning emblem, a flag floating its caress over a grave," which in turn alludes to the ways war graves were decorated, as depicted in the painting below. By drawing these connections to wartime deaths, Woolf suggests the impossibility of returning to normalcy after such horrific events ("white cottages, smoke going up- wore an extraordinary look of calm, of sunny peace, as if wisdom and piety had descended upon the dwellers there…But imperceptibly the cottage smoke droops […]"). This deep symbolism characterizes the post-impressionist style.

Félix Vallotton *The Cemetery of Châlons sur Marne* 1917.

Woolf's use of color differs from her counterparts in her attention to the qualities of light and time. Instead of portraying a scene in a literary context, she recognizes the wavering characteristics of hues and how they change based on time of day, reflecting the shimmering effects of light in real life. Thus her work reflects a post-impressionistic influence. Her ability to portray a scene like a painter instead of a novelist is evident in comparison to the work of her peers. Take for example the following excerpt from her estimable friend and peer, E.M Forster, who describes a similar scene of a bay and sea:

Love and life still remained, and he touched on them as they strolled forward by the colorless sea. He spoke of the ideal man– chaste with asceticism. He sketched the glory of Woman. Engaged to be married himself, he grew more human, and his eyes colored up behind the strong spectacles […]. He turned and looked at the long expanse of the sand behind.

"I never scratched out those infernal diagrams," he said slowly.

At the further end of the bay some people were following them, also by the edge of the sea. Their course would take them by the very spot where Mr. Ducie had illustrated sex, and one of them was a lady. He ran back sweating with fear.

"Sir, won't it be all right?" Maurice cried. "The tide'll have covered them by now." "Good Heavens…thank God…the tide's rising."

And suddenly for an instant of time, the boy despised him. "Liar," he thought. "liar, coward, he's told me nothing."…Then the darkness rolled up again, the darkness that is primeval but not eternal, and yields to its own painful dawn. (*Maurice* 6)

Forster's *Maurice* is a coming-of-age novel centered on a main male character, almost mirroring the general plot of *Jacob's Room*. However, this passage displays a drastically different emphasis, altogether ignoring color ("they strolled forward by the colorless sea"), which accentuates Woolf's unique style. Comparison to a similar scene in *Jacob's Room* underscores the contrast:

By six o'clock a breeze blew in off an icefield; and by seven the water was more purple than blue and by half-past seven there was a patch of rough gold-beater's skin round the Sicily Isles, and Durrant's face, as he sat steering, was the color of a red lacquer box polished for generations. By nine all the fire and confusion had gone out of the sky, leaving wedges of apple-green and plate of pale yellow, and by ten the lanterns on the boat were making twisted colors upon the waves, elongated or squat, as the waves stretched or humped themselves. The beam from the lighthouse strode rapidly across the water. Infinite millions of miles away powdered stars twinkled; but the waves slapped the boat, and crashed, with regular and appalling solemnity, against the rocks. (33–34)

Woolf's style is carefully crafted to reflect the Cézannian post-impressionistic technique, whereas Forster's depiction of the beach setting and time passing is explicit and lacks vibrancy ("The tide'll have covered them by now." […]. "Good Heavens…thank God…the tide's rising"). Forster's utter lack of color description and the focus on the characters highlights the unusual artistry and visionary nature of *Jacob's Room*. A fairly conventional if great novelist, Forster depicts his scene very plainly, noting the passage of time ("darkness rolled up") and mentioning the tide coming in. But not once does he mention any specific color and leaves the entire setting blank for the readers to imagine. In the contrasting passage, Woolf relentlessly focuses on colors and using color to evoke an emotional response. She even refers to her characters in this novel as "mosaic and splinters; not, as they used to hold, immaculate, monolithic, consistent wholes," bolstering how Woolf thought in painterly terms and considered her characters as daubs of color (Woolf Diaries II 314). She changes the colors the readers envision along with the setting sun, in parallel with real time ("[…] by seven the water was more purple than blue and by half-past seven there was a patch of rough gold-beater's skin round the Sicily Isles […]. By nine all the fire and confusion had gone out of the sky, leaving wedges of apple-green and plate of pale yellow, and by ten the lanterns on the boat were making twisted colors

upon the waves"), alluding to a Cézannian still-life. Like a true sunset, the colors in this passage warp and transform based on the perspective of the viewer and imitate how true colors in nature are never fixed, as in Cézanne's landscapes.

III: Cezanne and the Cubistic Perspective

Cézanne's late style is describable as "proto-cubism," meaning a style premised on "geometric schemas and cubes" (Green and Musgrove). This re-invention of style allowed Cézanne to further restructure perspectival planes and linear forms, resulting in block-work. The following piece, *Mont St. Victoire* (1904), best exemplifies this geometric form, further highlighting the resemblance to the later cubism movement.

Paul Cézanne *Mont St. Victoire* 1904.

This highly textured style greatly differs from his early works. Cézanne is no longer concerned with adhering to technicalities of time and space. Scholar Meyer Schapiro notes that this piece suggests "ecstatic release" and displays an oxymoronic "chaos" that is created through "clear vertical and horizontal strokes in sharp contrast to the diagonal strokes of the mountain and the many curving strokes of the sky [...] under all this turbulence of brushwork and color lies the grand horizontal expanse of the earth" (124). By implementing these various perspectives, Cézanne allows the viewers to glimpse into a fantastical multi-spatial and multi-temporal world that transcends reality. The viewer revels in feelings of god-like omniscience, viewing a scene from many angles simultaneously. Another example of this burgeoning style is Cézanne's Zola's House at Médan (1880), which uses bold colors to further investigate these differing temporal and spatial perspectives. His use of "carefully brushed, diagonal paint strokes" builds structure within the composition while simultaneously expressing the energy and emotion underlying nature itself (Boyle-Tuner). His intense color palette and heavy geometric brush work coax emotions out of ordinary landscapes. This system of building upon horizontal planes of color gradations to create depth anticipates Cubism while simultaneously referencing impressionist elements.

Paul Cézanne Zola's House at Médan 1880.

Cézanne's and Woolf's styles clearly overlap. When she introduced Jacob's Room (1922) as her "first truly experimental novel," Woolf made the deliberate choice to abandon traditional narrative (Woolf Letters III 409). Cubistic in its form, this novel differs from the fluid stream of consciousness of Mrs. Dalloway and The Waves in its choppy, almost geometric form, resulting in a masterpiece rivaling these later works of Cézanne. Unsurprisingly, Woolf was beset by the same fears and public contempt as Cézanne. Jacob's Room and post-impressionism received the same intense criticism. Both represented the "shock of the new" and stirred anxieties concerning "sexual identity" and "racial and national survival" (Lee 287). She writes in her diary regarding Jacob's Room:

I ought to be writing Jacob's room; —I can't, and instead I shall write down the reason why I can't [...] you see, I'm a failure as a writer. I'm out of fashion; old; shan't do any better; have no head piece; the spring is everywhere [...] what depresses me is the thought that I have ceased to interest people [...]. As a writer, there rises somewhere in my head that queer, and very pleasant sense, of something which I want to write; my own point of view. (Woolf Diaries VII 106–107)

Nevertheless, Woolf believed in herself as an artist and novelist, and stood behind the experiment of Jacob's Room, stating, "for one thing it might make some impression, as a whole; and cannot be wholly frigid fireworks [...] at last, I like my own writing. It seems to me to fit me closer than it did before" (Diaries VII 205). Cézanne similarly overcame his critics by developing confidence in his work. He wrote in a letter to his mother in September 1874:

I am starting to find myself stronger than all those around me and you know that the good opinion I have of myself is only the result of knowledge. I still have work to do, but not to obtain the admiration of idiots. And those things that are commonly admired so much are nothing more than the work of an unskilled labourer, the result of which is inartistic and common. I must to try to complete a work only for the pleasure of making it truer and more intelligible. And believe me, there is always a time when one gets the message across and one has greater admirers, more convinced than those who are only flattered by a vain appearance of the truth. (Brodskaïa 55)

The novel itself is obviously radical and intentionally crafted to be "free," meaning "structurally adventurous, less weighted down by tradition, shorter, more condensed and fragmentary" (Lee 430). Woolf constructs this novel by mirroring the multi-perspectival technique of Cézanne. Jacob's Room is largely told by secondary characters attempting to grasp the elusive Jacob. They present a non-linear, multi-perspectival narrative that simultaneously reveals the many sides of Jacob. The following passages about Jacob demonstrate this device:

'Distinction'– Mrs. Durrant said that Jacob Flanders was 'distinguished looking.' 'Extremely awkward,' she said, 'but so distinguished-looking.' Seeing him for the first time that no doubt is the word for him [...] distinction was one of the words to use naturally, though, from looking at him, one would have found it difficult to say which seat in the opera house was his, stalls, gallery, or dress circle. A writer? He lacked self consciousness. A painter? There was something in the shape of his hands (he was descended on his mother's side from a family of great antiquity and deepest obscurity) which indicated taste. Then his mouth– but surely, of all futile occupations this of cataloguing features is the worst. One word is sufficient. But if one cannot find it? (46)

'Jacob. You're like one of those statues...I think there are lovely things in the British Museum, don't you?' [...] 'I'm awfully happy since I've known you, Jacob. You're such a good man' [...] then Florinda laid her hand upon his knee. After all, it was none of her fault. But the thought saddened him. It's not catastrophes, murders, deaths, diseases, that age and kill us; it's the way people look and laugh, and run up the steps of omnibuses. Any excuse, though, serves a stupid woman. He told her his head ached.

But when she looked at him, dumbly, half-guessing, half-understanding, apologizing perhaps, anyhow saying as he had said, 'It's none of my fault,' straight and beautiful in body, her face

like a shell within its cap, then he knew that cloisters and classics are no use whatsoever. The problem is insoluble. (53–54)

Sustained entirely upon picture post cards for the past two months, Fanny's idea of Jacob was more statuesque, noble, and eyeless than ever. To reinforce her vision she had taken to visiting the British Museum, where, keeping her eyes downcast until she was alongside of the battered Ulysses, she opened them and got a fresh shock of Jacob's presence, enough to last her half a day […] she saw his face in advertisements on hoardings, and would cross the road to let the barrel-organ turn her musings to rhapsody. (113)

Woolf reveals Jacob through the eyes of those around him, oscillating between narrators and jumping through time and space. The choppy scenes bounce between characters, trying to define Jacob as a single tangible entity, like the first passage above, which flows through a series of questions to pin-point him ("A writer? He lacked self-consciousness. A painter? There was something in the shape of his hands…"). Such attempts to label Jacob (and the ultimate failure to do so) reflect the principles of cubism; at the core of this art form was freedom from the tyranny of the single perspective. Moreover, the cubistic characteristic of multiple perspective is a theme within Jacob's Room. As displayed in the above passages, none of the characters really know Jacob, though they intensely try to. The futile attempts by the characters to understand Jacob reveals his multi-dimensional nature, which proves impossible to encompass from a single standpoint. The readers are alone capable of seeing Jacob as a whole, as they assimilate every perspective presented in the novel to piece him together. The reoccurring comparison of Jacob to a statue highlights this insufficient, one-sided knowledge each character possesses of him ("Fanny's idea of Jacob was more statuesque, noble, and eyeless than ever"). They make assumptions based on the perspective available to them, like a three-dimensional statue. It's impossible to see a three-dimensional statue from a single vantage point. One must circle it in order to assimilate the piece in full. The same logic applies to Jacob. Jacob's full reality is hidden from his peers because they see only one side of him, from which incomplete view they generalize. His true self is imitated by fragments that redirect the reader's perception of him, slowly guiding the reader around Jacob, as for example when he responds to Florinda's advances and her belief that he is a "good man." He darkly muses that any excuse would serve a "stupid woman," and he tells her his head hurts in order to get away. The "problem" he addresses stems from his "inability to love" (which can also be read as his repressed homosexuality), which is uncomprehendingly highlighted through the narrations of those who love him. Only at the end of the novel does Jacob reveal that he feels his best when he's alone, remarking that "stretched on the top of the mountain, quite alone, Jacob enjoyed himself immensely. Probably he had never been so happy in the whole of his life" (95). Woolf highlights the impossibility of understanding Jacob through the eyes of others, emphasizing the cubistic perspective that requires many angles.

IV: Cézanne and Still-Lifes

Like Woolf, Cézanne adhered to some traditions, though in his own way. Famously known for his still-life "motifs," he would religiously paint the same scenes in different ways. In the following painting, he captures his reoccurring motif of fruit.

Paul Cézanne *Still Life with Curtain* 1895.

Scholar Nathalia Brodskaïa explains the significance of these subjects:

Cézanne never painted spheres, cones and cylinders; he preferred oranges, apples, peaches or onions. He laid out fruit and vegetables on a wooden table in his studio and alongside he threw a crumpled napkin and placed a Provencal decorated pottery jug or a wine bottle. The impressionist method, consisting of doing a quick sketch, did not suit him. Cézanne came to the studio every day, sometimes only to put two or three strokes on the canvas. Still life was for him the ideal genre: fruit and objects were patient, and they did not change. It was possible to paint them for a long time, for days, weeks and even months. Their colour also remained constant. For Cézanne, this colour was the basis of his canvases, the clay with which he assembled orange spheres or cylindrical jugs. Even when he painted a bouquet of flowers, these colours seemed artificial (or were artificial) there was no sign of life in them. But they possessed the beauty of distinct geometric forms. (62)

Thus Cézanne, like Woolf, clung to repetitions found within his subject matter. Such fixed forms and colors found in nature specifically inspired Cézanne to create, and in doing so paradoxically shifted the perspective of the viewer. With nature unchanging, he was able to warp time and space around it to produce unique pieces without becoming repetitive.

In *Jacob's Room,* Woolf uses imagery to depict a setting, but rather than simply describing it, she emphasizes every minute detail to philosophize it into significance before abruptly jumping to the next scene. This method creates Cézannian geometric fragments of time and underscores her modernity. Scholar Thomas Caramagno comments:

Critics readily acknowledge Jacob's Room's dreamlike, spasmodic incoherence, its rapid transitions, shifting perspective, and disconnectedness — evidences Woolf's modernity, but then they resort to hunting in the few specific details in Jacob's life for clues that would help to plug up the very large holes in the text with what is supposed to be Jacob's 'real' story, a more coherent story […]. Instead of reading symbols for their latent content, I will extend Virginia Blain's insight that 'Jacob's Room' relies on connecting the apparently disparate by setting up subtle trains of imagery which shift and modulate like a mirror of the narrative voice, creating a chain of perception wherein each new image reflects and contains the preceding one. (187)

Woolf uses such imagery to create what are in effect still-lifes. Take for example, the following still-life of Jacob's room:

Jacob's room had a round table and two low chairs. There were yellow flags in a jar on the mantelpiece; a photograph of his mother; cards from societies with little raised crescents, coats of arms, and initials; notes and pipes; on the table lay paper ruled with a red margin—an essay, no doubt— 'Does History consist of the Biographies of Great Men?' There were books enough; very few French books; but then anyone who's worth anything reads just what he likes, as the mood takes him, with extravagant enthusiasm. Lives of the Duke of Wellington, for example; Spinoza; the works of Dickens; the *Faery Queen;* a Greek dictionary with the petals of poppies pressed to silk between the pages; all the Elizabethans. His slippers were incredibly shabby, like boats burnt to the water's rim. Then there were photographs from the Greeks, and a mezzotint from Sir Joshua—all very English. The works of Jane Austen, too, in deference, perhaps, to someone else's standard. Carlyle was a prize. There were books upon the Italian painters of the Renaissance, a Manual of the Diseases of the Horse, and all the usual text-books. Listless is the air in an empty room, just swelling the curtain; the flowers in the jar shift. One fiber in the wicker arm-chair creaks, though no one sits there. (24)

This still-life underscores the utter lack of knowledge the reader possesses about Jacob. Woolf gives the reader only fragments of Jacob's character. These are brimming with symbolism, just as objects in a Cézannian still-life are deeply symbolic ("a Greek dictionary with the petals of poppies pressed to silk between the pages; all the Elizabethans. His slippers were incredibly shabby, like boats burnt to the water's rim"), allowing the audience to

infer Jacob without ever seeing him in full. Woolf further emphasizes this by placing the reader in a space representative of Jacob, yet devoid of him ("One fiber in the wicker arm-chair creaks, though no one sits there"). Thus, his room takes on greater significance, as each object described becomes a piece partially comprising Jacob, underscoring the fragmented and geometric nature of his character. Similarly, Woolf creates these still-lifes with a certain degree of increased emotion, as emphasized by the carefully crafted setting. As Cézanne does, Woolf consistently utilizes subtle movements within her still-lifes to heighten the emotional intensity of scenes, capturing tumultuous psychological moments in time for her characters. The final still-life portraying Jacob's room exemplifies this:

'He left everything just as it was,' Bonamy marveled. 'Nothing arranged. All his letters strewn about for anyone to read. What did he expect? Did he think he would come back?' he mused, standing in the middle of Jacob's room.

The eighteenth century has its distinction. These houses were built, say, a hundred and fifty years ago. The rooms are shapely, the ceilings high; over the doorways a rose or a ram's skull is carved in the wood. Even the panels, painted in raspberry-coloured paint, have their distinction.

Bonamy took up a bill for a hunting-crop.

'That seems to be paid,' he said.

There were Sandra's letters.

Mrs. Durrant was taking a party to Greenwich.

Lady Rocksbier hoped for the pleasure....

Listless is the air in an empty room, just swelling the curtain; the flowers in the jar shift. One fibre in the wicker arm-chair creaks, though no one sits there.

Bonamy crossed to the window. Pickford's van swung down the street. The omnibuses were locked together at Mudie's corner. Engines throbbed, and carters, jamming the brakes down, pulled their horses sharp up. A harsh and unhappy voice cried something unintelligible. And then suddenly all the leaves seemed to raise themselves.

'Jacob! Jacob!' cried Bonamy, standing by the window. The leaves sank down again.

'Such confusion everywhere!' exclaimed Betty Flanders, bursting open the bedroom door.

Bonamy turned away from the window.

'What am I to do with these, Mr. Bonamy?'

She held out a pair of Jacob's old shoes. (117-118)

The utilization of motion ("Pickford's van swung down the street. The omnibuses were locked together at Mudie's corner. Engines throbbed, and carters, jamming the brakes down, pulled their horses sharp up") contrasted with the near stillness within the bedroom ("listless is the air in an empty room, just swelling the curtain; the flowers in the jar shift. One fibre in the wicker arm chair creaks, though no one sits there") underscores the characters' intense feelings surrounding the death of Jacob. This still-life thus disassembles and disperses his life. When they see Jacob is gone, they are overcome with grief and confusion in the realization that they failed to fully understand him ('Jacob! Jacob!' cried Bonamy, standing by the window. The leaves sank down again"). This desperation to grasp Jacob is bolstered by the final fragment he leaves behind –his shoes– and the cyclical nature of the characters' confusion comes to a close ("What am I to do with these, Mr. Bonamy? She held out a pair of Jacob's old shoes"). The use of still-life to dismantle itself serves as an ending point for both the characters and the readers in their exploration of Jacob, who remains elusive and vague. This is further underscored by the lack of description of his room. In stark contrast with its first depiction, Woolf premises the scene on the continuation of life outside of the still-life, de-immersing her audience and drawing them back to reality outside of her painting. Scholar Jessie Alperin notes the significance of these still-lifes in her article The Aesthetics of Interruption:

The narrator frames the mundane aspects of life through a photographic still life of a domestic space that interrupts the narrative progression with an aesthetic still life [...] The whole novel is centered on finding Jacob's room and identity, but keeps being deferred by interruptions. When one finally finds the room, the deferral makes one forget what they were looking for and it becomes interruption itself. The description echoes a domestic

photographic still life that details and catalogues the room: 'Jacob's room had a round table and two low chairs. There were yellow flags in a jar on the mantelpiece; a photograph of his mother; cards from societies with little raised crescents, coats of arms, and initials' (Woolf 1922, 35). His room serves as a portrait of Jacob that preserves his belongings and himself through showing his presence. Yet, the air that fills the room, causing the chair to creak illustrates Jacob's absence and serves as a second portrait that supplements the stable catalogue with fleeting movement. Thef description ends with wind flowing through the room: 'Listless is the air in an empty room, just swelling the curtain; the flowers in the jar shift. One fibre in the wicker arm–chair creaks, though no one sits there' (Woolf 1922, 35). The air, like the visual silence, interrupts the description itself by causing movement, filling the absence of the room. Yet the wind is just an illusion of something there, like a ghost or a presence that is already dead. The air that flows through the room is thus a negative trace of Jacob, marking his presence through the imprint of absence amongst the objects that signify him. (19)

Woolf's explicit tactic of motion within her still-lifes is present in the initial description of Jacob, with Woolf staging the scene with deeply symbolic objects. She writes:

The little boys in the front bedroom had thrown off their blankets and lay under the sheets. It was hot; rather sticky and steamy. Archer lay spread out, with one arm striking across the pillow. He was flushed; and when the heavy curtain blew out a little he turned and half-opened his eyes. The wind actually stirred the cloth on the chest of drawers, and let in a little light, so that the sharp edge of the chest of drawers was visible, running straight up, until a white shape bulged out; and a silver streak showed in the looking glass.

In the other bed by the door Jacob lay asleep, fast asleep, profoundly unconscious. The sheep's jaw with the big yellow teeth in it lay at his feet. He had kicked it against the iron bed-rail.

Outside the rain poured down more directly and powerfully as the wind fell in the early hours of the morning. The aster was beaten to the earth. The child's bucket was half-full of rainwater; and the opal-shelled crab slowly circled round the bottom, trying with its weakly legs to climb the steep side; trying again and falling back, and trying again and again. (8–9)

This scene is wrought with metaphorical layers. The increasing intensity of motion ("The wind actually stirred the cloth on the chest of drawers[...].Outside the rain poured down more directly and powerfully as the wind fell in the early hours of the morning. The aster was beaten to the earth") heightens the significance of the surrounding objects. After the initial flitter of the cloth, the scene meanders before fixating on its first object: Jacob and his sheep's skull. Jacob is portrayed as sound asleep in the midst of a violent storm with a skull that represents his deceased father ("in the other bed by the door Jacob lay asleep, fast asleep, profoundly unconscious. The sheep's jaw with the big yellow teeth in it lay at his feet"), generates a deeply symbolic still-life that establishes the depths of his troubled nature. The scene then shifts with the increasing intensity of the storm, and readers are guided outside and presented with the second still-life: Jacob's bucket with the crab. The significance is explained by Thomas Caramagno:

Outside a storm lashes the house with a wild, intense energy that lacks any recognizable plot or order; it is "nothing but muddle and confusion." This strict division, spatialized as inner and outer, between meaning and unmeaning, conformity and innovation, schematizes the agitated depressive's subject object relations. Jacob's crab circling endlessly within a bucket aptly represents the boy's life under his mother's rule. He was, as Betty complained, "the only one other sons who never obeyed her" (23), but his wild nature, at home on the moors, is bounded by rigid circumstance shaped by her. (188)

This second still-life further attempts to explain Jacob's formulative experience, and helps illustrate his latter development. Thus Woolf crafts this still-life in the Cézannian mode, using the post-impressionistic techniques of abstraction and symbolism to suffuse ordinary still-lifes with pensive

uneasiness.

V: Realism vs Post-Impressionism

Equally reacting against the conventions of realism, Cézanne and Woolf seek to produce similarly impressionistic pieces, but by reversing traditional techniques. Instead of heavy brush work and high contrast, realistic scenes, they exaggerate color and abstraction. This still results in projecting feelings of the sublime, but subtly, unconsciously. Now, the subject matter no longer guides the viewer into these feelings, but instead such feelings are subjectively and uniquely projected onto each piece by the viewers' experiences. The following piece by Cézanne underscores these techniques:

Paul Cézanne *The House of the Hanged Man at Auvers-sur-Oise* 1873.
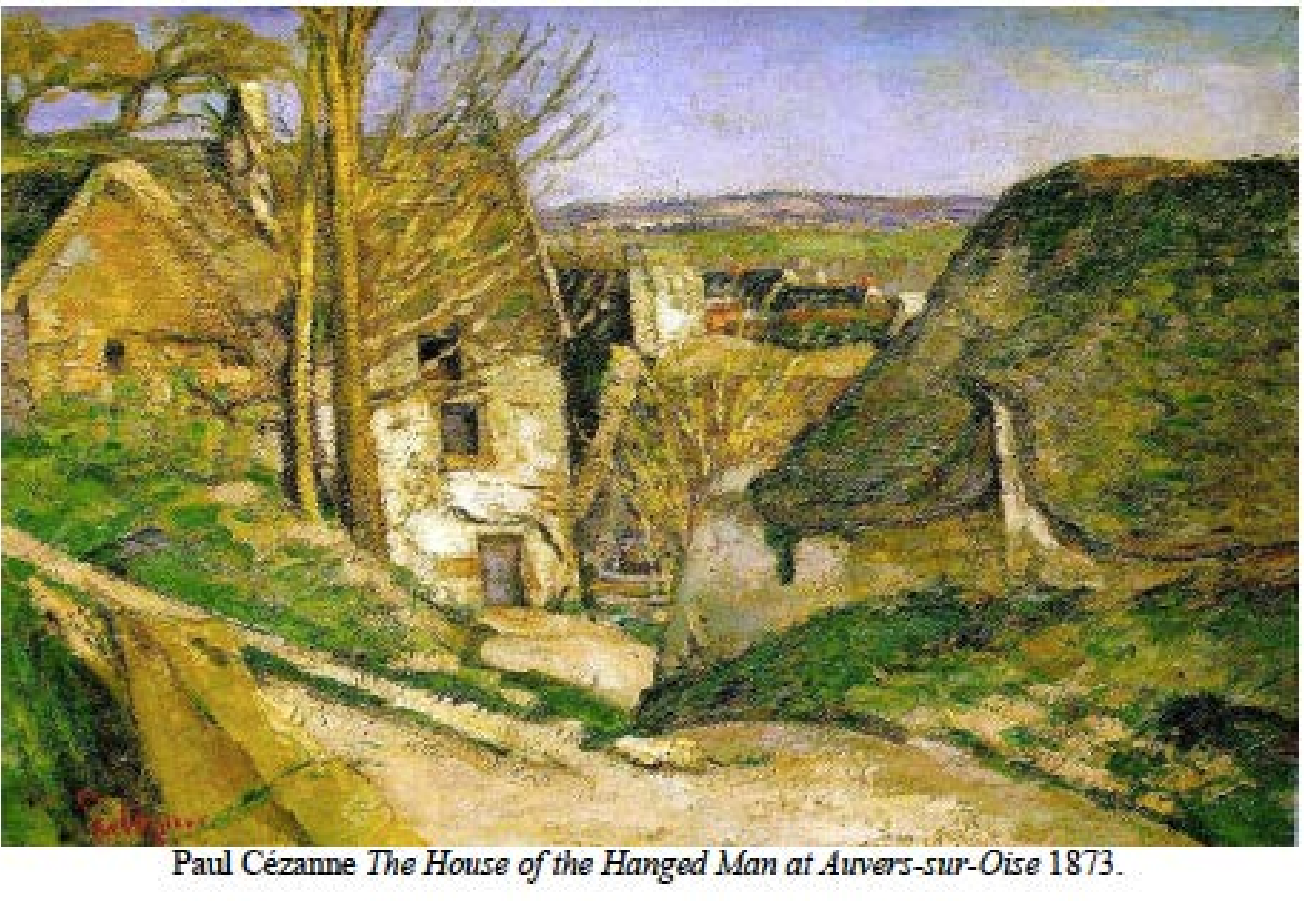
u This piece demonstrates the ways Cézanne formally rejected impressionism yet still preserved its emotional response. His characteristic brush stokes reconstructed the landscape as he saw it: ordered, geometric, vibrant. He demonstrated the need to control the sublime, to tame it. Instead of being overcome by the grandeur of nature, he instead played architect. Moreover, his iconic use of "motifs" is epitomized by the reoccurring depiction of a road in his pieces. As explained by scholar Nathalia Brodskaïa, the road motif "goes into the background along the middle of the canvas all the way to the bottom of the picture, accentuating the strictly centric composition: nothing more than a theatre stage [...] in his famous The House of the Hanged Man at Auvers sur-Oise, the street sharply drops between the houses, which form the side scenes, 'Imagine a work from Poussin completely redone from nature,' Cézanne said" (61).

By restructuring the scene, Cézanne acknowledges this sublimity— but indirectly and independently of the painting. Instead of showing explicit scenes and forcing a reaction, he strips away all the formal elements that were traditionally used to evoke a consistent collective response, giving viewers a chance to express their unique reaction based on their own perspective. This approach still entailed the attempt to elicit a response.

Similarly, Woolf completely reinvented the novel by reworking traditional Victorian forms. Although she began her writing career adhering to the strict styles of the 19th century, she used Victorian convention as a stepping stone to achieve a more advanced, post-impressionistic style. Take for example the following passages, the first from her early novel Night and Day (1919), the second from The Waves (1931):

Cassandra, sitting on the bed behind her, saw the reflection of her cousin's face in the looking-glass. The face in the looking-glass was serious and intent, apparently occupied with other things besides the straightness of the parting which, however, was being driven as straight as a Roman road through the dark hair. Cassandra was impressed again by Katherine's maturity; and, as she enveloped herself in the blue dress which filled almost the whole of the long looking-glass with blue light and made it the frame of a picture, holding not only the slightly moving effigy of the beautiful woman, but shapes and colors of objects reflected from the background, Cassandra thought that no sight had ever been quite so romantic. (344)

I have sat before a looking-glass as you sit writing, adding up figures at desks. . So, before the looking-glass in the temples of my bedroom, I have judged my nose, and my chin; my lips that open too wide and show too much gum. I have looked. I have noted. I have

chosen what yellow or white, what shine or dullness, what loop or straightness suits. I am volatile for one, rigid for another, angular as an icicle in silver, or voluptuous as a candle flame in gold. I have run violently like a whip flung out to the extreme end of my tether. His shirt front, there in the corner, has been white, then purple; smoke and flame have wrapped us about; after a furious conflagration [...]. Now I turn grey; now I turn gaunt; but I look at my face midday sitting in front of the looking-glass in broad daylight, and note precisely my nose, my chin, my lips that open too wide and show too much gum. But I am not afraid. (221–222)

The differences are drastic. Pre-existing Woolf's mature style, Night and Day provides a mimesis of manners and mores in the spirit of 19th century realism. She describes the scene as "romantic," and provides scene-fixing external detail: the "serious" and "intent" face, the "dark hair" and the large blue dress that "filled almost the whole of the long looking-glass." Such plainspoken descriptions coincided with 19th century realism, and Woolf's attempt to write such a novel indicates her Victorian roots. In The Waves, an almost identical scene— a character examining someone in a looking-glass—is radically different. Here, there exist only hints of her former style, as she still simply describes "lips that open too wide and show too much gum." Rather than merely depicting the scene she pulls the reader into a sinuous tangent that meanders through the character's inner experience. Jinny examines her physical self, but also looks deeper into her interior, in keeping with the fundamental aims of post-impressionism. The diction reflects her matured painterly style— "I run violently like a whip flung out to the extreme of my tether," and she artistically builds colors to add vibrancy to the scene— "his shirt front, there in the corner, has been white, then purple; smoke and flame have wrapped us about; after a furious conflagration." Woolf builds upon the 19th century tradition to produce a classic post impressionist work that still pays homage to her Victorian roots.

Conclusion: Bloomsbury Influence

Back in Monk's House, her country cottage in Sussex, Woolf settles down at her writing desk to compose a letter to her dearest friend and sister, Vanessa Bell. The early dusk of winter in Sussex compels her to turn on her desk lamp, and she tries warming herself under the glow of artificial light. The soft glimmer of the incandescent bulb casts the cozy sitting room in tones of muted orange and tall shadows, a stark contrast to the dreary grey of February skies outside. The new portrait of Quentin Bell, her nephew, hangs over her desk, urging her back to the task at hand. She picks up her pen and begins: "Sunday, 4 February 1940. My Dearest Vanessa, I've just been looking at my birthday present [...]. It's a lovely picture —what a poet you are with color —one of these days I must write about you. And I do enjoy having a picture of my dear Quentin" (*Letters VI* 381). Setting the letter aside, she casts her eyes slowly around the room, thinking of Vanessa's nearby home, Charleston. Woolf tried to imbue Monk's house with its spirit, decorating the interior in the post-impressionist style of the Bloomsbury artists. In the summer of 1916, Vanessa along with artists Duncan Grant and David Garnett moved into Charleston, which they conceived as an artistic sanctuary, a place to create uninterrupted. Amid WWI, Charleston provided them with the serenity needed to explore "intense, unconventional, artistic lifestyles" (Charleston and Bloomsbury History). Thus they began re-inventing their styles as artists and became recognized as "The Bloomsbury Painters." The Charleston Trust defines their work as "unthreatening, domestic and full of sensuous beauty," while simultaneously noting the heavy French post-impressionistic inspiration. It "touched both their easel painting and decorative art, while the influence of Mediterranean culture is apparent in the uninhibited colors and patterns of walls, ceramics and furniture decorations" (Charleston and Bloomsbury History). The house soon began to attract more noteworthy artists, writers, and theorists, such as Roger Fry, John Maynard Keynes. T.S Eliot, and E.M Forster. [19] Thus, "The Bloomsbury Group" was

solidified: a collection of intellectuals joined in opposition to the war and in search of deeper meanings within the realms of art, literature, and philosophy.

Woolf emulated her sister's provocative decor, being equally drawn to the aesthetic of French post-impressionism. British art bored her. She craved the bold colors that imbued French art. After moving into Monk's House with husband Leonard in 1919, Woolf immediately filled the house with French inspired, post-impressionistic pieces by Vanessa Bell, Duncan Grant, and other visiting artists (*Monk's House*). The aquamarine walls and hand-decorated furniture constituted a shrine to post-impressionism.

James Dobson *Monk's House Sitting Room*

Woolf's constant involvement with not only the Bloomsbury artists, but the larger French post-impressionist movement, infiltrated her writing. She immersed herself in this style of art and yearned to reflect its innovative techniques in her own works. In this she succeeded, with friend and art critic Roger Fry even noting that the emerging French post-impressionist artist Léopold Survage's paintings were "in parody" of Woolf's prose style (Woolf *Letters II* 385). Woolf continuously challenged herself to further interconnect post-impressionistic art and literature, going so far as to enlist Vanessa to design her Hogarth Press book covers in quintessential post-impressionist style, as seen below:
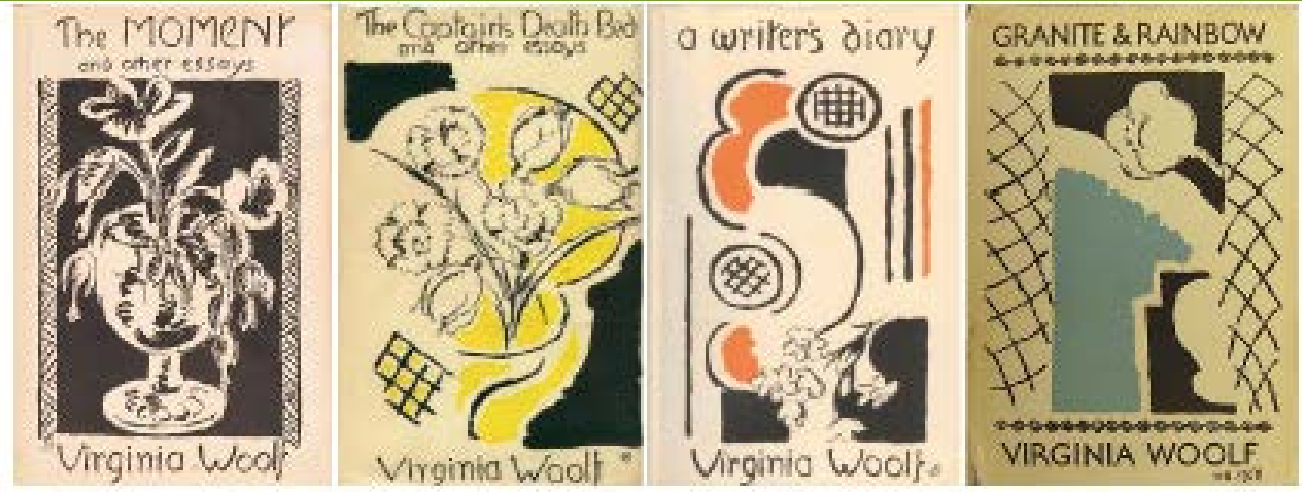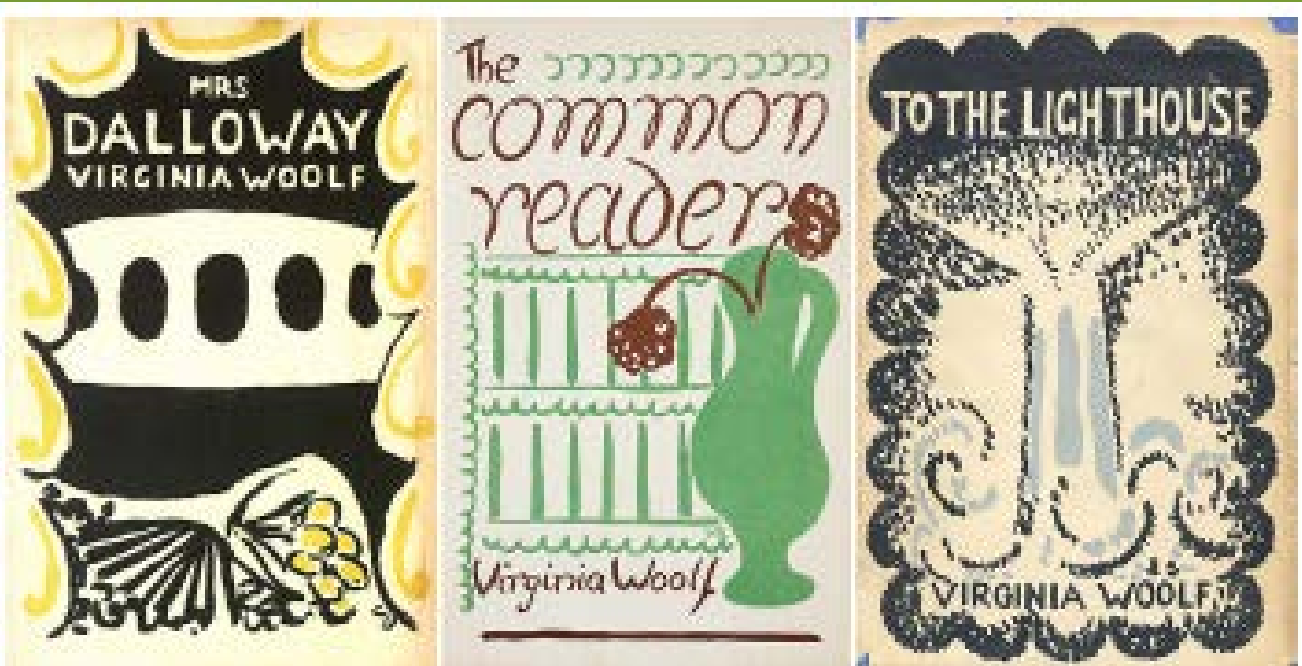
Vanessa Bell *Wood Cut Prints* 1920's-1940's.

Woolf was directly involved in the production and style of these covers. She writes in a letter to Vanessa concerning the design of the *Jacob's Room* cover:

We think your design lovely—Our only doubts are practical. L. thinks the lettering isn't plain enough, and the effect is rather too dazzling. Could you make the r of Room a Capital? And could the lettering be picked out in some color which would make it bolder? These considerations may spoil the design though. Here it is, in case you could alter it. (*Letters II* 544)

Woolf's engagement with these woodcuts suggests their important relation to her novels. She carefully oversaw all design production, and edited the covers to encapsulate the spirit of her novels. The style of these prints recalls post-impressionistic techniques of bold, contrasting colors, dissolutions of outlines, and free-flowing abstract forms. By physically and literally enveloping her work in such art, Woolf further aligns her novels with the post-impressionist movement.

The post-impressionist movement fascinated and beguiled Woolf. From her home to her friends and family, she was constantly immersed in it. This intertwinement between her writing and the French post-impressionist movement makes Woolf a post-impressionistic artist and her novels chapters in the history of art.

Note from UNC JOURney
This honors thesis in its entirety consists of an additional chapter. Due to size and publication restraints, we have only published a partial version of thesis.

Footnotes
[1] "The press contributed greatly to the record-breaking attendance at the exhibit by printing a flood of letters and articles about Post-Impressionism" (Twitchell 56).
[2] A total of four hundred people visited the gallery that day (Woolf Roger Fry 154).
[3] 3 Woolf notes that the paintings for this exhibition were hung by "standing on chairs," implying they were not at eye level, but rather above the viewer's head (Woolf Roger Fry 152).
[4] Woolf thought of herself as her "grandfather's grandchild," thus conventionalizing her first works out of respect to him and her male-dominated audience (Lee 213).
[5] See "Retrospect" in Vision and Design by Roger Fry.
[6] Steam of consciousness is defined as "indicating an approach to the presentation of psychological aspects of characters in fiction, it can be used with some precision...novels which have their essential subject matter the consciousness of one or more characters" (Humphrey 2).
[7] See Woolf's essay, Death of a Moth
[8] Twitchelly 25 and Lee 285
[9] Leonard Woolf served as secretary to Roger Fry during the second post-impressionist
exhibition in 1912 (Woolf Roger Fry 178).
[10] According to her letters, Vanessa Bell and
[11] Bernard Denvir notes in Post Impressionism "the term post impressionism first made an appearance in the summer of 1910 in the course of a discussion between two English critics, Roger Fry and Desmond McCarthy" (Denvir 7).
[12] Woolf travelled to Italy and Greece during the 1930's (Woolf Diaries V 153).
[13] Woolf acquired many paintings from her family and friends, such as Vanessa Bell, Roger Fry,
and Duncan Grant (Woolf Diaries V 121).
[14] Duncan Grant (1885-1978) was a British painter and close friend to Woolf and her sister.
[15] She mentions this in her letter to Vanessa Bell in 1919.
[16] Constructive brushwork is defined as "meticulously arranged marks that work together to
create geometric forms" (Richman-Abdouon).
[17] Cézanne is said to have chosen his studio location due to this olive tree. He built a small wall around it for protection and would "touch it, speak to it, and sometimes kiss it" ("Cézanne's Studio in Aix-en-Provence").

19] All had deep ties to Charleston House. John Maynard Keynes had his own room there, where he wrote The Economic Consequences of the Peace (1919), and Roger Fry undertook the entire development of the back garden (Charleston and Bloomsbury History).

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About the Author

Reanna Brooks graduated from UNC in December 2020. She earned her B.A in English with honors and highest distinction, and double minors in Latin and Studio Art. She always had a passion for art, serving as art editor-in-chief for UNC's literary magazine Cellar Door during her time at Carolina, and exhibiting her own work in the "Arts and Activism" exhibit on campus. It wasn't until taking Dr. Ross' "literary modernism" course her sophomore year did she discover the explicit overlap between art and literature, and more specifically, between post-impressionism and the writings of Virginia Woolf. Completely enamored, Reanna sought out Dr. Ross as an advisor and undertook her senior honors thesis further exploring this topic. Over the course of the most unconventional year of research, Reanna unveiled fascinating information that aligned Woolf's writing with specific post-impressionist artists. After graduating, she moved back to Charlotte for a gap year, where she teaches English full time at a local high school. She plans to pursue her PhD in English Literature and turn her undergraduate thesis into a completed dissertation.

SITA: Her Portrayal and Role In India

by Aleeshah Nasir

This research project will analyze the role of Sita in the *Ramayana* and compare it to the later versions of the *Ramayana* that looked to change the ending of the story. These versions include *Rama's Last Act* by Bhavabhuti and *The Dasaratha-Jataka* by Siddhartha Gautama. My research will first analyze what scholars have stated about Valmiki, Bhavabhuti and Gautama regarding their personal lives and beliefs. This will later guide me to figure out what the author's motives could have been in portraying Sita the way they did. From there, the research will focus on Sita herself and what she represents symbolically as a character and the effect she has had on the Indian culture. The next portion will analyze the different endings of these three stories and ultimately come to a conclusion about how these changes to Sita's character affected how the audience views her. In other words, whether the changes hindered or expanded her emotionally, physically, and symbolically and how can the effect of these changes be seen today in Indian culture.

Keywords: Sita, Valmiki, Bhavabhuti, Gautama, India

INTRODUCTION

Sita apparently has Vedic origins, but is first mentioned as the wife of Rama in Valmiki's Ramayana. She is and has been the symbol of devotion and sacrifice in Hinduism, making her the role model for many generations of women to abide by. Some consider her "a pawn in the power games - honor, nation, marriage, female chastity, fidelity, heterosexuality, abduction, revenge, rejection, class, military intervention and bravery - that men play," but they are clearly misinformed because Sita is more than just a pawn; she is a moral figure who encompassesa past and future culture in which the role of the wife and sister is deemed critical. Others view her as a symbolic reminder of "the statue of marriage as a self-evident and timeless institution, continually displacing judgment as to which kinds of sexual relationships are dharmic, or moral," which is an extreme understatement (Mangharam, 80). Only defining Sita in terms of her marriage degrades her as a character and destroys any inclination of her genuine self. The raw Sita is an independent woman capable of making her own decisions and having her own thoughts without the confinement of spatial labels. In the following article I am going to identify Sita as the moral figure in the Valmiki Ramayana, where she is the wife of Rama, and in the The Dasaratha Jataka by Buddha, where she takes on the role of Rama's sister. From there I am going to identify her characteristics as a raw character by analyzing her in Bhavabhuti Rama's Last Act.

VALMIKI AND THE *RAMAYANA*

Valmiki is the attributed author of the *Ramayana*. Currently there are two folk legends regarding his biography. One suggests that he was born into a family of brahmans and was enriched with vast wisdom; this theory is supported in the *Ramayana* itself, as Valmiki describes himself as the son of Pracetas (the Pracetas family were a group of influential Brahmins in ancient India). The other theory makes him out to be a bandit turned sage, which is supported by the view of the *Ramayana* as a poem in the bhakti orientation, in which sinners turn to worshipping god (Rao 9518).

Either way, Valmiki and his epic the *Ramayana* have left a lasting impact with it being considered one of the great epics, alongside the *Mahabharata*, in India. The *Ramayana* is orchestrated in a way that allows the audience to engage and experience the norms of their culture. It is, as one scholar calls it, a story of "personal and public relations" and the decision-making process. But it's also a story that follows the "guiding context of the universal divine, masters and gurus." The Brahma gifted Valmiki the story of Rama and the sloka verse, a new poetic form through which to tell the story. In return,

Valmiki is to write the Rama through the "sloka meter" about the story of earth. This is significant because it implies that the epic was a means of bringing about the Hindu culture and Indian traditions with varying concepts - duty, work, morality, justice, etc. (Misfud 224-229).

The story itself follows the main character Rama—the incarnation of Vishnu and successor to the throne of Ayodhya—who is exiled for fourteen years. His half brother Lakshman and beloved wife Sita join him, unable to witness Rama go into exile alone. Sita ends up getting captured by the demon Ravana, catalyzing a series of adventures that Rama and Lakshman go on in order to retrieve her. Once they do retrieve her, Rama does not take her back until she proves to him that she is chaste by jumping into fire. Sita survives and Rama takes her back, but the people of Ayodhya continued to gossip about Sita's supposed adultery with Ravana, so Rama banishes her to the forest. There she gives birth to Rama's two sons Lava and Kush who are finally reunited with their father after a few years. Rama calls for Sita to again prove her innocence, but this time she asks Mother Earth to swallow her—which Mother Earth does. The epic ends with Rama jumping into a nearby river because of the overwhelming grief from losing his wife (and others) following his actions.

The *Ramayana*, being one of the oldest epics in India, not only offers a glimpse into the societal, cultural, and political realm of ancient India, but it also exerts great influence in the India of today. The text presents its readers with characters in which an ideal king, wife, husband and brother can be found — ideals that the culture and religion of India still believes, follows, and has expectations for (Ramesh).

Having discussed the role of Sita as the wife of Rama, I will further develop her as a moral figure by identifying her as the sister of Rama. An important thing to point out before the next analysis is that *The Dasaratha-Jataka* is a whole revision of the *Ramayana*. The Valmiki *Ramayana* revolves around Sita's kidnapping by Ravana, but *The Dasaratha-Jataka*, by setting up Sita as a sister, disregards the struggle of two lovers and in doing so, ignoring the concept of love and a lover's struggle.

SIDDHARTHA GAUTAMA'S *THE DASARATHA-JATAKA*

The Dasaratha Jataka is a well known text in the Buddhist

religion. There has been debate about whether this text was the first "crystallization" of the Rama story or if it was written after Valmiki wrote the Ramayana. The author attributed to this text is the Buddha himself, which is widely accepted by Buddhists. This is because The Dasaratha Jataka is included in the Jataka commentary which is a collection of jatake stories that Buddha is thought to have preached at the Jetavana monastery (Richman 53).

The story starts off with a man grieving over his father's death who is visited by The Master. The Master tells him a story about the past in which a king named Dasaratha had three sons — Rama, Lakkhaṇa, and Bharata —and one daughter known as Lady Sita. The young queen Kaikeyi asks the king to allow her son Bharata to become the next ruler of the kingdom. Dasaratha denies her this and, fearing that the queen may kill his other two sons (Rama and Lakkhana), asks them to leave for twelve years, only to return after he has died. Sita, the devout sister, joins them. The king dies after nine years and Bharata goes in search of Rama. Bharata, Lakkhana, and Sita grieve over their father's death, but Rama does not shed a single tear. When asked why he is not mourning, Rama states it is because all life must eventually come to an end, so a wise man should not take the effort and time to grieve over a natural process. Bharata, Lakkhana, and Sita return to the kingdom, but Rama stays the extra three years to fulfill his father's request and eventually comes back to reign for sixteen thousand years (Gautama).

The peculiar thing about this story, as already stated, is that Sita is the sister of Rama rather than his wife. One possible explanation for this deviation may be the religious differences between Hinduism and Buddhism regarding marriage between husband and wife. The Buddha himself was married, but left behind his wife and child in order to focus on achieving enlightenment. Because of this, in the Buddhist religion marriage is not denied, but nor is it encouraged.

This switching in roles from wife to sister also switches the responsibilities and morals tied to each character. Sita as a wife was devoted and loyal to her husband, with these qualities tested through trials. The need for trials is a sign that the wife has the ability to deviate from her devotion and loyalty. The sister Sita, on the other hand, does not have the ability to deviate. Unlike a wife, she is and always will be devoted and loyal to her brother. The sister Sita does not carry the same tribulations as the wife because there is a sense of trust between the brother and sister that cannot be broken versus that of the wife and husband. One possible explanation for this could be that brother and sister have the same blood running through their veins, and thus to break this trust would be an insult to natural law. In the Hindu tradition itself there is the celebration known as Raksha Bandhan that celebrates the bond that a brother and sister share. This long tradition, although Hindu, may have influenced the Buddha to cast Sita as a sister rather than a wife, but not completely abolish her from the story because of a need for a loyal and devout female.

On the other hand is the intimate relationship between a husband and wife that a brother-sister relationship could never obtain. Although there is a mutual familial love between siblings, the love between Sita and Rama as husband and wife encompasses a realm of compassion and desire. This compassion and desire is the sole source of the heart-wrenching poetry present in Valmiki's *Ramayana* as well as Bhavbhuti *Rama's Last Act*. But as mentioned in the last paragraph, the tribulations facing a wife are different than those of the sister. These afflictions are cultivated as jealousy and questioning of loyalty. Unlike the loyalty between siblings which was an outcome of nature, the loyalty between a husband and wife was developed and thus implies that it can be broken (as can be identified by the multiple times Sita was asked to prove her purity and innocence in the *Ramayana*).

BHAVBHUTI *RAMA'S LAST ACT*

Now that the moral Sita has been identified and analyzed, the discussion can progress to ask: who is the raw Sita? Thus far she has only been contextualized as the wife and sister of Rama, but who is she without Rama? Unlike *The Dasaratha Jataka*, *Rama's Last Act* does not retell the whole story with major plot changes. Instead, it provides its readers with the same original characters in their same roles, with only the ending changed. This static architecture of the story makes it easier to contrast Rama's Last Act to the Ramayana and pull out the characteristics only defining Sita.

Bhavabhuti, picks up the story of the Ramayana after Sita has proven her chastity by going through fire, and Rama and Sita went to their kingdom. At the ending, however, instead of separating Rama and Sita like Valmiki did, Bhavbhuti reunites the two lovers. This reunification of lovers was not first done by Bhavabhuti, as prior works such as the Padma Purana and Jaimini Bharata did the same thing, but he was the first to have overtly romantic scenes between the two, thus appealing to his readers in favor of the hero and heroine. Because of Bhavabhuti's need to please readers, some critics question his motivation to reunite the lovers as an act of pillage rather than an act of kindness. This is because the reunification of lovers, as some argue, can be associated with the return of Sita's subordination to her husband Rama. For example, Pratap Kumar states that Valmiki depicts Sita as "independent, bold, and strong in mind" and that Bhavabhuti does the opposite by depicting her as "delicate, sensitive, and easily shaken up by Ramas feelings." He argues that in the Valmiki Ramayana, Sita chooses to cast herself into earth because she is a woman of self-respect and is tired of proving her innocence. Although Kumars evaluation is one way to interpret the ending of the Valmiki Ramayana, this is somewhat of a false statement because Sita is not completely autonomous in her decision. She clearly buckles to Rama's request by willingly casting herself into the earth to once again prove her innocence. To further complicate his argument, I would like to point out —does wanting to be reunited with one's husband and children have to be a sign of defeat? Is there not a sense of female empowerment by giving Sita the happy ending she deserves, or does Sita have to give up her own desires in order to prove her independence? I understand that Sita reuniting with Rama may only end up bringing the heroine despair by later on having to prove her innocence again, but that is the fault of Rama, not Sita. Her ability to stand strong as a female character in the face of trouble and remain just as kind and compassionate as ever is not a fault. Those are the exact qualities that many women in India point out when idealizing her (Kumar).

LASTING EFFECTS

As mentioned in the preceding paragraphs, Sita is still widely revered as the ideal woman to live up to and be in India. Although many, especially the Euro-Western culture, may mock the Indian culture for admiring a figure characterized as weak due to her so-called loyalty and subordination to her husband, to many women in India she is quite the opposite. When women in India favor Sita, they are not "endorsing female slavery;" they are instead endorsing her love and her forgiveness. The idea among Euro-Western countries to unconsciously regard attributes of another religion or culture as submissive is accredited to global feminism and its mistaken identity of the savior complex. The savior complex hinders feminism at its roots because no longer is the discussion about equal opportunities and treatment of males and females, but rather the mocking—and sometimes brutal attacks — of other women perceived as submissive. These so-called signs of submissiveness may be from the hijab that a woman wears due to her religion, or the figures they look up to in their culture such as Sita (Chowdhury). The women of India are able to detach Sita from her role as a wife and view her in terms of a female. She is seen as someone "whose sense of dharma is superior to and more awe inspiring than that of Rama." By doing so, they are not blocking Sita's good qualities by putting her in context to Rama, but rather enhancing them, making her qualities and characteristics a sign of empowerment rather than imprisonment (Kishwar).

The problem of highlighting and idealizing Sita only occurs when the patriarchal society places pressure on women to try to become and act as though they were reincarnations of Sita in a subordinate sense. This in turn leads to women resenting Sita as an ideal figure, as well as allowing other countries and cultures to attempt to degrade this epic and thus India as a country. But one thing to realize is that this epic is more than just the cultural aspects of India: it has today reached further

than the borders of India and become relevant worldwide.

Take for example the millions of South Asian immigrants living in North America who grew up listening to this story. In particular, pay attention to the South Asian women who relate to Sita today in the United States because of the struggles she faced in the epic corresponding to the struggles they face as immigrants. The need to prove themselves to a foreign country and its people, just like Sita had to prove her innocence and purity to Rama and people of Ayodhya: the need to take care of themselves when they are alone, like how Sita was when she was banished; and the need to be careful of walking alone at night in fear of being kidnapped or raped, like how Sita was captured by Ravana (Murphy and Sippy).

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Using Concept Algebra to Build Quantitative Models of Genre: an Ethnomusicological Case Study of Merengue and Bachata

by Niazi Murataj

Concept algebra is a novel denotational mathematics that enables the rigorous codification and analysis of discursive thought. Concept algebra (CA) is applied to Ethnomusicology, the study of traditional forms of music, to illustrate how traditionally qualitative discourse can be computed into a potentially machine-readable format. Literature on the methodology of ethnomusicology is analyzed to judge the appropriateness of applying a mathematical method. An in-depth historiography of Bachata and Merengue is constructed. The historiography of both genres is used to operationalize denotational concepts for each genre using the CA Object-Attribute-Relation model. These denoted concepts are screened for similarity using CA operations. Merengue and Bachata are shown to share around a third of their musical attributes quantitatively. Recommendations are made for computational extensions of this framework, and the method's applicability to other fields in the humanities.

Keywords: concept algebra, denotational mathematics, ethnomusicology, digital humanities, music, machine learning

INTRODUCTION

On its surface, this exploration is about comparative analysis in ethnomusicology. At a methodological level, this exploration seeks to justify the use of denotational mathematics for representing discursive thought. To that end, this exploration begins with discursive thought and then reframes the same using a method based on Yingxu Wang's *concept algebra*. The ethnomusicological application of this method is done performatively, to motivate potential applications of this method in other humanities by qualified authors.

With the advent of the digital humanities, modern musicologists evolved increasingly mathematical methods for studying music e.g., computational musicology, systematic musicology, and digital musicology. Mathematics has successfully been introduced into broader musicology (e.g., vector-based representation of musical intervals).

In contrast, there is a consensus weariness of mathematical-computational methods in ethnomusicology. Midcentury attempts at mathematics-based comparative analyses of ethnic music were criticized due to Eurocentric assumptions built into the models (e.g., the analysis in Merriam 1969). As a result, ethnomusicological consensus steered not only form comparative analysis, but from mathematical models in general. This avoidance of mathematical methods is unwarranted.

In the last decade, a new denotational mathematics called *concept algebra* was developed that enables flexible representation and analysis of rigorously defined abstract concepts. Ethnomusicology would benefit from adopting this flexible, mathematical approach as it facilitates criticism and discursive clarity. This paper applies concept algebra to ethnomusicology to illustrate the possibility for transparent discursive thought that relies on *a posteriori* research-derived conceptual definitions rather than opaque *a priori* assumptions.

The purpose of including concept algebra in a humanities field is not simply to flex intellectual muscle or introduce complexity for complexity's sake. A reader not trained in mathematics will find concept algebra far more tractable than analytical mathematics. Concept algebra serves to make bare the author's thought process (including misconceptions and biases) via methodical conventions, facilitating critiques and discourse. Minimal training is required, and the additional effort helps the author make their argument accessible to the reader.

In the context of this exploration, concept algebra provides a method for modelling ethnic genres simply. The author establishes a representation of Merengue and Bachata, and then uses algebraic operations to evidence abstract comparative measures such as "similarity." This symbolic representation confirms intuition provided by a comprehensive treatment of the background of these two genres. With this performative exploration come several motivations for extending this method beyond the narrow scope of this paper.

The central claim of this paper is that transparent, comparative ethnomusicological analysis with a non-insignificant degree of objectivity is possible with concept algebra; to illustrate this claim, the comparability of Bachata and Merengue will be denoted and analyzed.

LITERATURE REVIEW: ETHNOMUSICOLOGY & ITS METHODS

Modern and traditional sources were selected based on their authority and their coverage of methods already used in empirical ethnomusicology. The texts are put into conversation to extract a consensus on the viability of applying scientific (specifically, quantitative) approaches to ethnomusicology, as well as to identify any limitations that should be considered when using the proposed mathematical approach. This proves difficult, as ethnomusicology discourse is fraught with competing viewpoints.

Even consensus on the *definition* of ethnomusicology is nonuniform. Bruno Nettl, a pioneer in this field, argues that ethnomusicology is both the comparative, global study of musical art *and* the study of music through an anthropological lens (Nettl 1983). Nettl stops short of qualifying ethnomusicology as a social science, but indicates that the field would benefit from syncretism with the scientific paradigm. He urges experimentation with interdisciplinary approaches, particularly mathematical methods (Nettl et al. 1965, 174).

Claude Palisca, recognized for his work on medieval music, dissents. Palisca states that musicology is characterized by its inextricability from history. He explicitly *excludes* those approaches in the same "community" as the methods of the sciences (qtd. in Merriam 1969, 213-29) as inappropriate for ethnomusicology. It is unclear whether Palisca would consider denotational mathematics as members of the scientific "community" of methods.

On the other hand, Alan P. Merriam, whose expertise in global musical traditions is well-established, advocates for a middle way. He asserts that the study of ethnomusicology, being a hybrid discipline located between the 'thrusts' of the humanistic and anthropological (read: scientific) approaches, is best executed through a balance of methods from either side of this dichotomy (Ibid.). It must be noted that all three authors delineate a dichotomy between "humanistic" and "scientific" methods, although the reader is left without an explanation of where to draw the distinction (past the fact that "scientific" and "anthropological" are similar).

This methodological line is particularly unclear where comparison is concerned. In regular empirical discourse, comparisons are often necessary—this is a common fact. However, the consensus disavows comparative methods, as indicated by the field's methodological split from comparative musicology.

The older study of comparative musicology, epitomized by the "Berlin School" of Hornbostel, Sachs, and Stumpf (Merriam 1977, 197), is considered the precursor to ethnomusicology. Comparative methods were common in this earlier form of ethnomusicology, but the current literature's treatment of these methods is mostly negative. Bruno Nettl epitomizes the consensus view on comparative methods when he asserts that comparative musicology is bunk due to the inherently Western-centric paradigms forming the basis for its comparisons (Nettl 1965, 169). Others, empowered by quantitative methods, disagree.

Linton C. Freeman, a comparative musicologist, together with Merriam et al., argue that quantitative anthropological methods should be applied to objectively compare between musical styles (Freeman et al., 1956). Freeman et al. apply a statistical model (a rudimentary t-test) to a case study comparing the music of the Ketu people of Brazil and that of the Rada of Trinidad. The authors insinuate that this statistical model is objective as it focuses on musical characteristics (occurrence of major/minor intervals), rather than value judgements. But Nettl's assertion holds—the major-minor paradigm is inherently Western, detracting from Freeman's claims of statistical objectivity. Freeman et al.'s use is vulnerable to criticism, and their results fail to justify comparative methods on the grounds of structural bias. However, the inappropriateness of comparative methods does not extend to all mathematical methods.

In attempting to understand the methodology of ethnomusicology for establishing the suitability of an empirical analysis, this consensus poses a significant hurdle. Applying computational methods to draw conclusions across large musical samples is rendered difficult due to the overwhelming opinion against comparison. This aversion limits the usefulness of the scientific approaches encouraged by Bruno Nettl in his foundational *Theory and Method in Ethnomusicology* (Nettl 1965, 174); if quantitative ethnomusicological methods are to be applied, a compelling tradeoff between the consensus warnings against comparison (and reductionism) must be established vis-à-vis the benefits derived from empirical approaches.

More recent developments in the literature of a parallel field—that of musicology—indicate that the use of mathematical methods can support qualitative judgements of music invisible to human judgement alone. Nicholas Cook, a modern systematic musicologist, shows the usefulness of quantitative methods by applying computational acoustic modelling to visualize Ligeti's Lux Aeterna; Cook's analysis offers unique insight into the *form* of the composition that confirm intuition and reveal additional details (Cook 2004, 103-26).

Cook's experiment testifies to the usefulness of quantitative methods in both affirming extant discourse and contributing new knowledge. In that same vein, a method that operationalizes genre rigorously and increases discursive transparency procedurally could be useful.

It must be noted that some of the literature offers different, more complete qualifications of ethnomusicology than the aforementioned leading experts–qualifications which imply more methodological flexibility. The Society of Ethnomusicology (SEM)—the acclaimed U.S.-based institution which publishes the journal Ethnomusicology—offers a coherent definition of ethnomusicology as "the study of music in its social and cultural contexts" ("About Ethnomusicology").

SEM states that ethnomusicologists examine music as a "social process" to identify its contextual ontology (i.e., "what is music in context of culture and society?") and meaning. It asserts that ethnomusicology is "highly interdisciplinary," and that the "coherent foundations" for its methods are the employment of a "global perspective," the understanding of music as a context-dependent "social practice," and the importance of "ethnographic fieldwork" and "historical analysis". SEM's qualifications are not at odds with comparative analysis, and echo Merriam in his discussion of a "balance" between "humanistic" and "anthropological" approaches. Contextual analysis is inherently comparative—one cannot establish context without distinguishing it from other contexts. Social phenomena are intersubjective and therefore comparative—their study must also be comparative.

Ergo, some degree of comparison in ethnomusicology is permitted if it is to be studied in sociocultural contexts; however, implied value judgements are not permissible when making comparisons (e.g., using the Western equal temperament system to describe non-Western musical forms).

Concept algebra offers an ideal quantitative framework for comparative, but unbiased, analysis. Rather than rely on preconceived notions of music (such as tones and semitones), concept algebra allows an ethnomusicologist to *construct* an expedient (temporary or permanent), culturally-appropriate substitute concept for more precise, context-aware analysis.

With this context-based, sociocultural operationalization of ethnomusicology's methodology in mind, this analysis attempts to establish relations through the formal representation of ethnomusicological conceptualizations of two Dominican genres: Bachata and Merengue. This denotation is undertaken with the goal of analyzing *comparability*, rather than explicitly making comparisons. Such a comparability analysis can be further extended to make research judgements, or as a starting point for more sophisticated quantitative analysis.

METHOD: CONCEPT ALGEBRA

This section is meant to be a broad overview of Concept Algebra (CA). CA is a denotational mathematics invented by Yingxu Wang of the University of Calgary which fuses formal logic, denotational mathematics, set theory, and cognitive science to yield a tool for the "rigorous manipulation and elaboration of abstract concepts and their algebraic operations" (Wang, 2015). Concept Algebra can be used to rigorously denote complex sets, such as human concepts, by simulating them within an abstract discourse. The analysis below assumes elementary familiarity with set theory, although some knowledge of discrete mathematics helps.

CA replicates core processes in human thought via three

sets of *operators*. The *operands* of CA operators are concepts. For analogy, the plus (+) and (-) signs are arithmetic *operators* representing the processes of addition and subtraction. The *operands* of these arithmetic operators are numbers.

CA has three classes of operators corresponding to classes of human cognitive actions: relative, reproductive, and compositional operators. For the purposes of this paper, only relative operators are explored. The relative operators (denoted ·r) are *related/independent* (↔\↮), *sub/super* (<\>), *equivalent/nonequivalent* $(=\backslash\neq)$ and *similar* (~). Relative operators are binary operators i.e., they take in two concepts and yield a common measure of interest.

Concepts are operationalized as per Wang's definition: a basic cognitive unit for denoting a real entity and/or perceived object (Wang 2015, 62). These concepts are context-dependent on the *discourse* that produces them. Wang abstracts the concept of "discourse" by assembling a hypothetical set (here, a collection of interrelated concepts). This set is called the "universe of discourse" and is denoted ; when unspecified, it represents any and all concepts that can be conceptualized or addressed in any discourse (Ibid.).

The universe of discourse is further divided into three subsets of objects, attributes, and relations and is denoted $\mathfrak{U} \triangleq (\mathfrak{O}, \mathfrak{U}, \mathfrak{R})$. $\mathfrak{O}$ represents *objects* (a physical instance and of an abstract concept), and $\mathfrak{U}$ represents attributes (a related, but dependent, quality or concept used to provide specific and contextual details), and $\mathfrak{R}$ signifies relations (random, potentially meaningful matches of object-object, attribute-attribute, object-attribute, attribute-object) (Wang 2015, 64). This is referred to as the Object-Attribute-Relation model (OAR). The set operationalized above is the general form of concept-specific OAR relations.
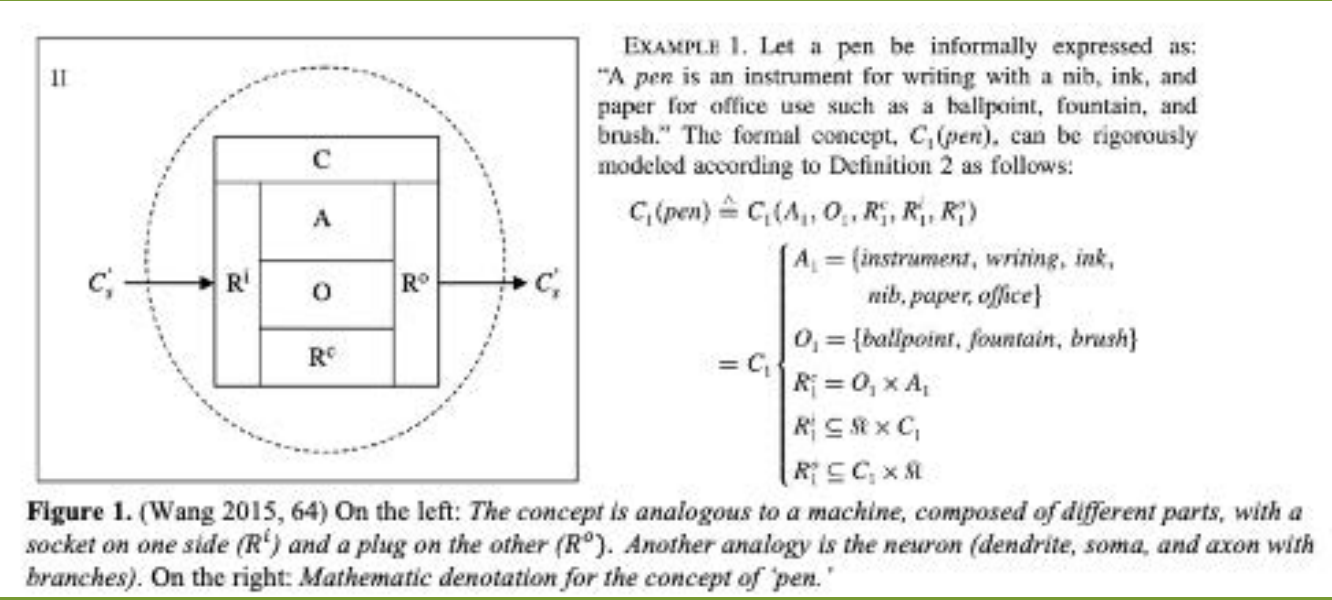
Additionally, the concept of knowledge level functions in tandem with the universe of discourse. It is a way of representing all present knowledge about a concept and about the frameworks to which the concept belongs. This knowledge level is denoted $\mathfrak{R}$ (Ibid.).

A concept is denoted as $C \triangleq (A, O, R^c, R^i, R^o)$ where the attribute subset A is a proper subset of the power set of (i.e., the set of all possible subsets of $\mathfrak{U}$ Note that is a "hyper inclusion" (read: subset) of the universe of discourse $\mathfrak{U}$ erred to as a 'hyper structure'), denoted as $A \subset p\mathfrak{U} \subset \mathfrak{U}.$ wise, $O \subset p\mathfrak{O} \subset \mathfrak{U}.$
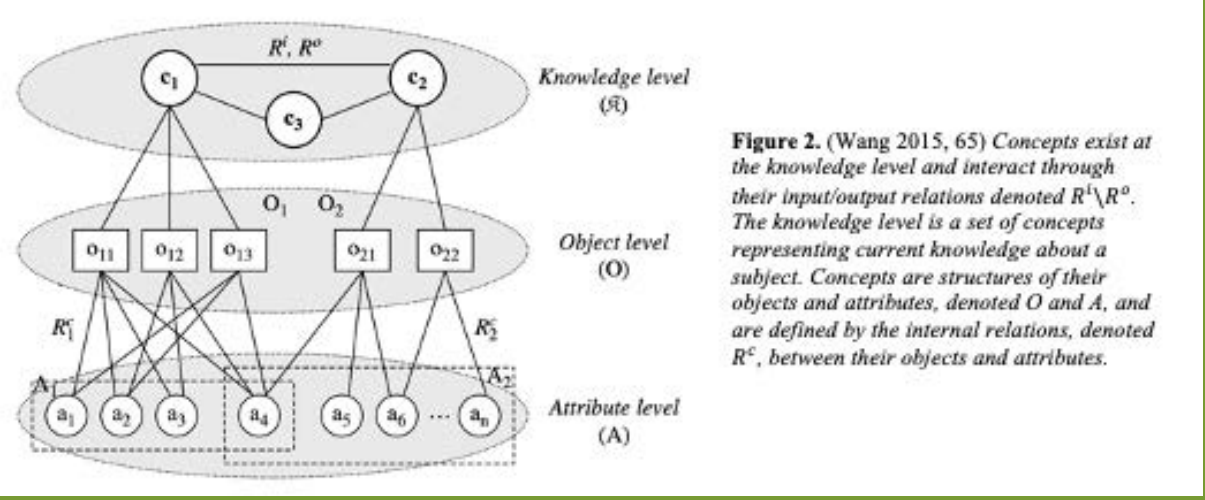
The R subsets are three sets of a set of relations $R^n \subset p\mathfrak{R} \subset \mathfrak{U}.$ Each subset stands for a different class of relations: *internal relations* between *objects* and *attributes* of a concept (R^c), *input relations* between external knowledge and a concept (R^i), and *output relations* between a concept and external knowledge (R^o). In symbols:

$$R^c \subseteq O \times A$$

$$R^i = C' \times C : C' \subset p\mathfrak{O} \subset \mathfrak{U}, C' \neq C$$

$$R^o = (R^i)^{-1}$$

Thus, concepts can be abstracted as diagrams (see figure 1):

EXAMPLE 1. Let a *pen* be informally expressed as: "A *pen* is an instrument for writing with a nib, ink, and paper for office use such as a ballpoint, fountain, and brush." The formal concept, $C_1(pen)$, can be rigorously modeled according to Definition 2 as follows:

$C_1(pen) \triangleq C_1(A_1, O_1, R_1^c, R_1^i, R_1^o)$

$A_1 = \{instrument, writing, ink, nib, paper, office\}$

$O_1 = \{ballpoint, fountain, brush\}$

$R_1^c = O_1 \times A_1$

$R_1^i \subseteq \mathfrak{R} \times C_1$

$R_1^o \subseteq C_1 \times \mathfrak{R}$

Figure 1. (Wang 2015, 64) On the left: *The concept is analogous to a machine, composed of different parts, with a socket on one side (R^i) and a plug on the other (R^o). Another analogy is the neuron (dendrite, soma, and axon with branches). On the right: Mathematic denotation for the concept of 'pen.'*

CA concepts, together with its operators, provide a framework by which to model non-rigorous cognition. Concepts exist as the highest-level operands in CA, and different concepts can share attributes while remaining distinct (see (A) in figure 2).

Figure 2. (Wang 2015, 65) *Concepts exist at the knowledge level and interact through their input/output relations denoted $R^i \backslash R^o$. The knowledge level is a set of concepts representing current knowledge about a subject. Concepts are structures of their objects and attributes, denoted O and A, and are defined by the internal relations, denoted R^c, between their objects and attributes.*

For more information on Concept Algebra, please consult "Concept Algebra" by Yingxu Wang in the Journal of Advanced Mathematics and Applications Vol. 4, 62–87, 2015. This exploration only uses those parts of CA which are relevant to comparative analysis.

The forthcoming historiography on Bachata and Merengue is first explored traditionally, and then using CA. A comparative analysis is established without relying on a priori notions.

ETHNOMUSICOLOGICAL HISTORIOGRAPHY OF BACHATA & MERENGUE

Bachata and Merengue are musical forms from the Dominican Republic, with marked differences despite their common origin. The musical elements of each are first situated within the appropriate sociocultural and historical context, before operationalization using the OAR model. Once context is established and understanding is cemented, rigorous definitions are built using the aforementioned $C \triangleq (A, O, R^c, R^i, R^o)$ model.

Geopolitical History of the Dominican Republic

The Dominican Republic is a state occupying the eastern, Spanish-speaking half of the Caribbean island of Hispaniola. Prior to the arrival of Columbus in 1492 the island was known by the local Taino as "Quisqueya" (Manuel et al. 2006, ch.5). This nation's history comprises of a long colonial period spanning from 1500-1795, followed by a period of severe regional conflict and culminating with a series of dictatorships (Ibid.).

Spanish colonial rule in Santo Domingo lasted until 1795, when it was succeeded by French colonial rule (Manuel et al. 2006, ch.5). In 1822, French colonial rule was succeeded by a period of Haitian occupation which lasted until 1844 (Ibid.). Despite autonomy, the region was not stable nor prosperous; extreme weather, weak political and economic institutions, and rule by a succession of strongmen known as *caudillos* plagued the nation until the early 20th century (Ibid.). The country was driven into crippling debt due to mismanagement and conflict with neighboring Haiti.

This period is epitomized by an episode involving one particular *caudillo*: in 1861 dictator Pedro Santana, immensely indebted to international creditors, attempted to cede his nation back to Spain and be named governor (Gonzalez and Wiarda, 2019). Spain returned to the island from 1861, before withdrawing its troops in 1865. Santana's actions did not repel his international creditors.

In the early 20th century, investors from the United States and Europe–concerned about the Dominican Republic's debt–threatened to take action. In 1905 the U.S. began running the nation's customs agency to liquidate European debts, so to avoid collections (Gonzalez and Wiarda, 2019). The U.S. sent thousands of Marines to the island from 1914 through 1924. (Manuel et al. 2006, ch.5). U.S. Marines had a distinct musical legacy on the island.

The genealogies scrutinized agree that Marine occupation was a period of relative peace (Manuel et al. 2006, ch.5) (Gonzalez and Wiarda, 2019). Soldiers built schools and infrastructure, introduced baseball to the island (now an athletic staple), and enforced property reform benefiting U.S. companies (Gonzalez and Wiarda, 2019).

It should be noted that there was local resistance to these incursions, and that abuses of power were not uncommon (Manuel et al. 2006, ch.5) (Gonzales and Wiarda, 2019). The U.S.

Marines established a modernized military force which was instrumental to the rise of the Dominican Republic's future authoritarian governments (Ibid).

The situation reached its nadir after president Horacio Vasquez, installed in 1924 with U.S. support, was ousted in 1930 by a people's revolution exacerbated by economic mismanagement in the aftermath of the great depression (Manuel et al. 2006, ch.5). The aforementioned military apparatus, led by future dictator Rafael Trujillo, let the public overthrow Vasquez. Upon the revolution's success, Trujillo seized power and established a totalitarian dictatorship which lasted until 1961, qualified as one of the most monstrous in modern history (Gonzales and Wiarda, 2019).

Trujillo was famously nepotistic and controlled the church, schools, entertainment, and even the toponomy of his nation: Santo Domingo was renamed Ciudad Trujillo (ibid.). He privatized industries for personal profit and closed the nation off to the outside world, demanding that his people live in his idea of an idyllic agrarian society– going as far to destroy his own railways to discourage "vain" travel (Manuel et. al ch.5, 2006). Trujillo's pathological personality had a tangible effect on the development of the "orchestra" style of Merengue.

As Trujillo grew increasingly paranoid, his regime grew increasingly brutal. His methods, at first lauded by oblivious foreign media as "miraculous," drew international enmity (Gonzales and Wiarda, 2019). As the 1950s came to an end, Trujillo discovered several internationally-backed plots to topple him and initiated his own transnational intrigues: he sent Dominican agents to assassinate Venezuelan president Romulo Betancourt in June 1960 (Ibid.). As a result, in 1961 the CIA organized local dissidents to assassinate Trujillo (Manuel et al. 2006, ch.5).

Trujillo's heirs were driven out and Juan Bosch, with his *Partido de la Liberacion Dominicana* (PRD), took power in 1963 on a progressive-liberal ticket (Ibid.). Unfortunately, friction with the Dominican oligarchy and Bosch's threat to establish a *de facto* democracy free of U.S. influence led to his ousting (Gonzales and Wiarda, 2019). The U.S., fearing that communism could be installed in the Dominican Republic, sent 20,000 marines to repress revolts on the island in 1965. The 1966 elections were organized under U.S. supervision, and Joaquin Balaguer– a former ally of Trujillo– was elected (Ibid.).

Balaguer increased the power of business, created a military-industrial nexus, and promoted foreign investment (Gonzales and Wiarda, 2019). Unlike Trujillo, Balaguer allowed emigration. Many Dominicans emigrated to the U.S. (Manuel et al ch.5, 2006). Urbanization increased; the country had been 70% rural, but Balaguer's policies created rapidly urbanization as foreign investors pushed lower-class persons off valuable farmland and into city slums (ibid.). The emergence of Bachata was a direct consequence of this rapid urbanization.

Balaguer's focus on the economy at the expense of social justice, and to the benefit of oligarchs, left large segments of the population dissatisfied. He was briefly succeeded by PRD candidates Antonio Guzman Fernandes in 1978, and in turn by Jorge Blanco from 1982 until 1986 (ibid.). Balaguer re-assumed power in 1986 for ten more years before being forced to reign (ibid.) (Manuel et al. ch.5 2006).

The geopolitical realities of the Dominican Republic had massive effects on Dominican society and on the formation of a cohesive Dominican identity. Transitively, these realities shaped the music and art of the Dominican people.

Dominican Society and Identity through History

Before Columbus, Quisqueya (the indigenous name for Hispaniola) was inhabited by the Taino people. With Spanish colonization and the institution of slavery, which introduced persons of African origin to the island, a hierarchical demography emerged mirroring caste systems in other Spanish and Portuguese colonies. The racial hierarchy introduced by imperialism during the 16th century (*mulatto, indio, creole,* etc.) has pertained throughout Dominican history. The middle and upper classes traditionally identified with Spain (Manuel et al. 2006, ch.5).

Afro–Caribbean identity in the Dominican Republic manifests as a unique plexus. In *Caribbean Currents*, Manuel et al. note that "three-quarters" of the population of the nation is mulatto. However, due to wars with Haiti, persons of African heritage euphemistically refer to themselves as *indios* or *indios oscuros* (Manuel et. al ch.5, 2006).

Dominican nationalism in general developed in opposition to Haiti rather than to Spain.

Despite this cultural repression of overt expression of Afro-Dominican identity, culture in the Dominican Republic retains some aspects that are markedly African. Veneration of West-African *misterios* by *cofraidas*– respectively loose parallels to the Cuban concepts of *oricha* and *cabildos*– are still venerated in some parts of the country (Ibid.). Proximity to Haiti has also lent itself to various cultural influences, both musical and ritual, such as the gaga celebrations and Voodoo-inspired *Rada* (Ibid.).

Under Trujillo, Afro–Dominican aspects of the nation's cultural tapestry were relentlessly oppressed (Manuel et al. 2006, ch.5). Trujillo himself repressed his Afro-Dominican identity; he would reportedly lighten his skin with powder (ibid.). He worked with the church to repress religious expressions with characteristics of African heritage.

It must be noted, however, that despite this plexus of the Afro-Dominican identity within the wider frame of Dominican nationalism, Dominican conceptions of race are generally fluid and tolerant (Manuel et al. 2006, ch.5). Dominican class relations are equally complex, and the myriad salient identities within the Dominican tapestry are rife with intersectionality.

As with any identity, the national plexus is reactionary: it is developed in response to an encroaching, differentiating influence. Just as the Dominican-Haitian enmity manifests itself culturally as an aversion to the expression of a dedicated Afro-Dominican identity, so does the wider Dominican national identity manifest as a counterreaction to foreign encroachment. Bachata and Merengue both developed as a consequence of the rapport of 'self' against 'other.'

Merengue: El 'Perico Ripiao'

Manuel et al. dub the Merengue as the Dominican Republic's "most important" genre and assert it to be "a product of syncretic creolization" (Manuel et al. 2006, ch.5). In context of the nation's history and identity, this claim holds and is easily defensible. Merengue music has undergone drastic changes with notable influences from a myriad of styles, not least of all Haitian styles (as in the case of *cibaeño Merengue*). The Merengue serves as more than an energetic, meaningful set of conventions: it is one of the threads that binds the tapestry of a cohesive Dominican national identity.

The word Merengue is purportedly derived from *maringa* of Mozambique origin, and is divorced from its Spanish meaning (Ibid.). Its early history is obscured but it is thought to have begun in the mid 19th century, based on reconstructions, as a creole variant of a family of closely-related "syncopated" couple dances across the Caribbean islands such as Puerto Rican *danza* and Cuban *contradanza* (Paul Austerlitz qtd. in Manuel et al. 2006, ch.5). A Haitian connection is likely. It originally emerged as a salon music that was predominantly European in origin. Outside of ballrooms, popular forms of Merengue flourished– marked by "Afro-Caribbean flavor" with vivacious rhythms and ending in call-and-response sections (Ibid.).

The lyrics of Merengue dealt with variety of topics and were used as a medium for social commentary (Ibid.). Like other Caribbean creole music, these emergent folk Merengue forms were denounced as distasteful and vulgar by the societal elite. Among the countryside, they continued to thrive and diversify into several styles, such as *mangolina, pambiche,* and the famous *cibaeño Merengue*.

During the late 19th century, the originally guitar-based Merengue was adopted and formalized by ensembles consisting of accordion, the *guira* scraped idiophone, a two-sided goat skin drum called the *tambora*, and the *marimba* (a bass instrument related to the Cuban *marimbula*). Styles varied depending on region, giving rise to such conventions as the *mangolina* (marked by its 6/8 meter) and *pambiche* (aka the 'Yankee' Merengue, influenced by Marine occupation) (Ibid.). The genre came to be characterized by fast tempo, made for dancing.

The Cibao valley Merengue eventually emerged as a standardized style adopted by bandleaders such as Tono Abreu and Nico Lora (Manuel et al. 2006, ch.5). It should be

noted that the Cibao region is to the north of the Dominican Republic, bordering Haiti; Haitian influence is noticeable in the rhythm of this style. In the standardized *Merengue tipico cibaeño*, a characteristic tambora plays a roll while the guira provides a lively percussive timbre to the texture– often in "mutating counterpoint" (Ibid.). The accordion, an anchor for the melody, provides a "dazzling, shimmering" staccato *picadito* accompaniment (Ibid.) Many *Merengue tipico* ensembles also incorporate the saxophone for fast arpeggios. Overall, this gives the Merengue an energetic–sometimes described as "manic" or "glib"– characteristic sound.

Many Merengues begin with a march-like paseo for a few measures in the beginning, and transition to the verse section, termed the Merengue per se. The typical choreography to the *paseo* is a leisurely stroll around the floor (Ibid.). The music then segues to a lively call-and-response section termed the *jaleo* (or *mambo* in modern cases) (Manuel et al. 2006, ch.5). As far as form is concerned, the Merengue is similar to Cuban *son*. However, its simpler harmonies of "generally alternating tonic-dominant chords," fast tempo, and basic two-step choreography serve to distinguish it from related styles (Manuel et al. 2006, ch.5).

Class dynamics influenced the development of different Merengue styles. The traditional Merengue of Cibao, typical to weekend parties called *pasadias* and popular in taverns near Santiago de los Caballeros (the provincial capital of Cibao valley), was markedly considered "lower-class." It was in Santiago de los Caballeros that this popular style of Merengue was termed somewhat quizzically *"Perico Ripiao,"* meaning "Ripped Parrot:" either referring to a particular tavern or to the style's bright and energetic nature (Manuel et al. 2006, ch.5).

The *orquesta Merengue*, on the other hand, developed as the music of the upper echelons of Dominican society. It incorporated a brass ensemble and resembled European ballroom music, finding easy international popularity due to its "exotic" driving rhythms. Rafael Trujillo and his brother, Petan Trujillo, were avid proponents of this style of Merengue.

Petan, who controlled the Dominican entertainment industry during his brother's regime, made sure to embed orquesta Merengue into the national consciousness by inundating the radio with it. Trujillo himself mandated that all street musicians play Merengue in the *orquesta* style, and jailed those who did not play it correctly (Manuel et al. 2006, ch.5). He was so enamored that he brought his favorite orquesta, the renowned Orquesta Luis Alberti, to the capital and renamed them "Orquesta Presidente Trujillo." Trujillo made Merengue the country's official music genre (Ibid.).

Manuel et al. state the popular 1937 piece "El compadre Pedro Juan" by Luis Alberti epitomized Merengue's peak popularity in bourgeoise salons over waltzes. This popularity was preceded by a chain of influential musical and geopolitical events. Saxophone-incorporating brass-bands led by Juan Espinola and Pavin Tolentino (among others) adapted the Merengue to a salon style (Ibid.). This "salonization" made Merengue more palatable for middle- and upper-class persons, who had always preferred European waltzes to the "erotic," "crude" *Merengue tipico* (Ibid.).

Before salonization, Merengue had already cemented itself as Dominican. The 1916 U.S. occupation drove Dominicans of all classes to define themselves cohesively in opposition to the encroaching "Yankee." As the Merengue was native to the island, the bourgeoise embraced it as a symbol of the Dominican national identity as opposed to American influences, abandoning European waltzes and foxtrots (Ibid.) Nico Lora's "La Protesta," still performed today, exemplifies this reaction, with the social commentary in this Merengue acting as a sort of national rallying point (Manuel et al. 2006, ch.5).

Likewise, the Merengue "La Muerte del Chivo" (the death of the goat), celebrating Trujillo's assassination, serves that same purpose of social commentary and mutual identity-formation in another context—happiness at the death of an oppressor. In this sense, the Merengue is multifunctional: music for both dance and social commentary/cohesion. Merengue is characteristically versatile.

After Trujillo's death, the U.S. invasion in 1965, and Balaguer's opening of the country to the outside world, Merengue continued to adapt. The art form faced international competition: rock, salsa, and ballads all threatened to replace it as the preferred genre in the

Dominican Republic. Until the end of the 1970s, the Dominican Republic lacked a musical industry; however, by 1980, the budding musical industry was dominated by Merengue. Merengue's quality of production drastically improved. Innovators like Johnny Ventura modernized a *Merengue tipico moderna*, using the electric bass rather than the marimba, with a disco-inspired "kick." This revitalization offered an attractive alternative to increasingly bland, commercialized, and synthetic salsa (Manuel et al. 2006, ch.5).

Ventura's innovation internationalized Merengue, finding popularity first in Puerto Rico. It accompanied Dominican immigrants into New York City. The modern Merengue exuded the Dominican concept of *tigueraje* ("swagger"), and made for a serious radio competitor for salsa and other Latin American musical styles (Manuel et al. 2006, ch.5).

Merengue further evolved in the club scene of New York City's Washington Heights. It picked up flashy, commercialized, internationalized characteristics, taking a life of its own as a globalized genre. Merengue was the first style to challenge salsa's claim as the only commercialized music with "Latin" characteristics.

Typical Merengue was characterized by its distinctive tambora rolls, fast tempo, and lighthearted lyrics. Modern Merengue substituted tambora rolls for the *a lo maco* pattern, the saxophone for accordion parts, and has added supporting trumpet riffs. The *fusilamiento*—speeding up the tempo and adding crisp, sassy *jaleos*— has added to the music's "manic" mood (Manuel et al. 2006, ch.5). As was the case with typical Merengue, and in spite of its rhythms, the choreography for modern Merengue is subdued, constating of rocking in time with the beat– known as *paso de la empalizada*– in positions of varying intimacy. This is supplemented by individual flairs.

Bachata: Canciones de Amargue

Bachata is a young genre when compared to Merengue. Bachata originated in the musical form and harmonic style of Cuban bolero, brought over to Hispaniola at the end of the 19th century by Sindo Garay (Manuel et al. 2006, ch.5). The roots of the style would have been serenades or rural dances. The term originally meant an informal romantic piece for the guitar. The genre per se evolved in ensembles of the early 20th century comprising of guitars, maracas, and sometimes bongos, guiras, tamboras, and marimbas (Manuel et al. 2006, ch.5). The lyrics were marked with innuendo and made no attempts to veil their ribaldness. Expectedly, Bachata was frowned upon by the bourgeois as overly sexualized and vulgar (Ibid.).

Trujillo worked to oppress Bachata and promote Merengue. Thus, Bachata only flourished after his death the late 1960s when Balaguer took power and opened the nation to foreign investment. The influx of foreign agribusiness and the subsequent displacement of villagers from their lands produced the downtrodden cultural context in which Bachata fruited. Thousands of Dominicans were driven into the slums by rapid urbanization and ended up in derelict shantytowns termed *Villas Miserias* (Manuel et al. 2006, ch.5). It was amidst these mud roads and open sewers, ignored by Balaguer's government, that Bachata was disseminated on cassettes and played in street-side *colmados* (establishments fusing grocery shops and cafes).

Bachata never became recognized as a symbol of national identity nor cohesivity like Merengue. Well-off Dominicans purportedly termed it *chachivache*, meaning trivial, and its name invokes a sense of disapproval; a Bachata is a derogatory term that means a rowdy, lower-class party. In many aspects, Bachata had arisen in opposition to Merengue. Whereas Merengue was played in expensive clubs inaccessible to the broader public, Bachata was played by street vendors in the slums. Yet by the 1980s, despite being much younger as a style than Merengue, Bachata came to rival it in popularity and sales (Manuel et al. 2006, ch.5).

Bachata's original audience was the *concón* (a word meaning the burnt rice at the bottom of a pan) of Dominican

society, but it quickly achieved international prominence. Bachata was not meant as political commentary. Like the Bolero which influenced its origin, the sentimental Bachata portrayed emotions of longing, sadness, and incompletion reflective of the plights of male *Villa Miseria* dwellers (Deborah Pacini Hernandez qtd. in Manuel et al. 2006, ch.5). The lyrics reflect feelings of *amargue* (bitterness) stemming from male perceptions of city life, unemployment, relationships, perfidiousness, and inadequacy. Criticism of urban women is common in early Bachata. Lighthearted songs were ribald and replete with double-entendres.

In the 1990s, Bachata experienced something akin to the *fusilamiento* of Merengue. Anthony Santos, Joe Vera, and Raulin Rodriguez upped the tempo and swapped the finger-picked acoustic for an amplified acoustic while maintaining traditional arpeggio accompaniments (Manuel et al. 2006, ch.5). The crestfallen, angry, and macho lyrics were eventually supplanted by sensual, sentimental, romantic text. Female Bachata artists, such as Melida Rodriguez, began to emerge in contrast to the genre's traditional male style. Artists such as Juan Luis Guerra also helped rid Bachata of its stigma as lower class and unacceptable.

Today, Bachata has been internationalized. Groups such as NYC's Aventura prove its transnationality. Puerto Rican communities in New York City's Lower East Side enjoy it just as much as the Dominican communities in Washington Heights.

Expectedly, internationalized Bachata has taken on new forms. Inter-genre collaborations, such as those of Aventura or Romeo Santos, fuse hip-hop with Bachata.

With the context and details of these genres identified, denotational mathematics can be applied to analyze where these details intersect at a conceptual level. The forthcoming analysis elegantly synthesizes the discourse above into denotational concepts permitting for CA operations.

APPLYING CONCEPT ALEGRBA TO ETHNOMUSICOLOGICAL CONCEPTS

Ethnomusicology is the subset of the universe of discourse.

$$\mathfrak{U}_e = (\mathfrak{O}_e, \mathfrak{U}_e, \mathfrak{R}_e) \sqsubset \mathfrak{U}_\square$$

Where:

· is the universe of discourse of ethnomusicology.

· are the instantiations of the tangible objects of music (such as instruments or songs).

· is the set of ethnomusicological attributes (such as locations and social customs).

· is the set of relations between the above that give them contextual meaning.

It should be noted that the above definition can be defined as convenient for the researcher. The more details that are incorporated into this rigorous definition, the more accurate the analysis. The most rigorous analysis is that which is most transparent, most replicable, and contains minimal latent *a priori* elements.

Key to concept algebra are the ideas of intension and extension. These are derived from computer science. The intension of a concept (which can be thought of as a class) is the set of its building blocks (its fields) and its relations with other concepts (its methods) (Wang 2015, 63). The extension of a concept is all of its instantiations (i.e., manifestations in reality) (Ibid.). In the example of the "pen" concept, Wang illustrates the intension of the pen {instrument, writing, ink, nib, paper, office} as the Attribute (A) subset, and the extension of the pen as the object set (O) of {ballpoint, fountain, brush}. Those objects share the attributes specified in the intension.

Thus, when discussing musical genre in an ethnomusicological context, the intension of these genres, denoted as the *attributes* of the genre, should be information on elements proprietary to the genre (i.e., what distinguishes it from others, what characterizes the genre) and any functional 'operations' (i.e., a specific style or way of playing that links genre characteritics in a recognizable way) that define it (i.e. *picadito, jaleo, a lo maco* etc.). The objects of the concept/class are instantiations of these intensions; for example, staccato would be an object of *picadito*, and *jaleo* is a potential object of call-and-response.

The internal relations R^c would be the cartesian product of A and O within a concept, interpreted to symbolize some sort of relation between the two components, e.g.

$$C \cong (A, O, R^c, R^i, R^o); \ A = \{1,2,3\}; \ O = \{x,y,z\}; A \times O \equiv R^c =$$
$$\begin{pmatrix} (1,x) & (2,x) & (3,x) \\ (1,y) & (2,y) & (3,y) \\ (1,z) & (2,z) & (3,z) \end{pmatrix} = A \times O \equiv R^c$$

The implications here are two-fold. The way that objects and attributes are related within a concept implies that the internal relations which define a concept are the product of its atomic attributes and objects. This in turn implies that the atomizations of these objects and attributes are subsequently related, and also contribute to the nuances of the concept.

This can be illustrated with a specific case. Let concept 'C' represent Merengue with 'A' = {jaleo, mambo} and 'O' = {call-and-response}.

Then, R^c = {(jaleo, c&r), (mambo, c&r)}.

In turn, let C_{jaleo} have A_{jaleo} = {lively, catchy, traditional}, and O_{jaleo} = {syncopation, riff}, and let $A_{mambo} \sqsubset C_{mambo}$ = {hard-driving, complex, novel} and O_{mambo} = {syncopation, interlocking rhythm}.

Also, let $A_{c\&r} \sqsubset C_{c\&r}$ = {call, response} and $O_{c\&r}$ = {phrase, progression}. Then, $A \times O = \{A_{jaleo} \cup A_{mambo} \times A_{c\&r}\} \times \{O_{jaleo} \cup O_{mambo} \times O_{c\&r}\}$ Expanding this elaborated cartesian product would offer more insight into the particular nuances of the R^c. This internal relation is also called the *semantic* relation of a concept and is the basis for simple extra-contextual comparisons (e.g., Merengue is 'bourgeoise,' whereas Bachata is 'proletarian').

The R^i and R^o stand for input and output relations (I/O relationships), which are defined as inverses of each other. These are also termed the *syntactic* relations between concepts because they relate concepts to one another. $R^i = \mathfrak{R} \times C$ whereas $R^o = C \times \mathfrak{R}. \mathfrak{R}$ (a stylized 'K') stands for the knowledge level, i.e., the extent to which the CA framework has be applied. These relations show the connectability of other knowledge to the concept (an input relation) versus the relation of the concept itself to other knowledge (an output relation). Context itself can be abstracted as a network of syntactic relations that exists in $\mathfrak{R}$, such that only a subset of the semantic relations of the concepts therein are accentuated, effectively changing the concepts as they relate to each other. Context can be thought of as the function which determines how R^i and (which are inverses of each other) behave.

Note that when establishing a rigorous definition of a concept as per the $C \cong (A, O, R^c, R^i, R^o)$ model, several iterations of this atomization processes must be performed for accuracy (to ensure that the operationalized concept is replicable through multiple attempts). The objects and attributes previously included which are not deemed to be accurate after repeated operationalizations should be omitted from future operationalization of the concepts under scrutiny. These should be explicitly included in the argument for transparency.

Once rigorous definitions of Bachata and Merengue are established, a cascade of CA operations is performed, starting with the relation operation. A relation is denoted as:

$$C_1 \leftrightarrow C_2 \cong A_1 \cap A_2 \neq \emptyset \vee R_1^i \cap (R_2^o)^{-1} \neq \emptyset \vee R_1^o \cap (R_2^i)^{-1}.$$

This means that there exists some non-empty set of common attributes between Bachata and Merengue, or some likewise nonzero input-input or output-output sets of intersecting relations between Bachata and Merengue.

Once a relation is established, the degree of operationalized similarity can be gauged through such actions as the similarity operation: $C_1 \sim C_2 \cong \frac{|A_1 \cap A_2|}{|A_1 \cup A_2|}$ on provides a quotient which approximates similarity as attributes in common over combined attributes not in common. A dissimilarity operation can be derived by taking the inverse of similarity, which would be the negative reciprocal.

With the rigorous denotation for the concepts of Bachata and Merengue established, algebraic manipulation of these denotations can be achieved. The denotations are manipulated with the goal of establishing a basic model to depict the

"comparability" between the two concepts. This involves mathematic experimentation with the denotation. The goal is to derive a set of proportions and products that can be mapped for a visual representation of the interaction between the ethnomusicological concepts of Bachata and Merengue.

COMPARING BACHATA AND MERENGUE USING CONCEPT ALGEBRA

$$C(Merengue) \cong C_M(A_M, O_M, R_M^c, R_M^i, R_M^o) \text{ and } C(Bachata) \cong C_B(A_B, O_B, R_B^c, R_B^i, R_B^o)$$

are established through an atomization of the sociocultural, musical, and relational components as examples of *intensions* or *extensions* of the overarching concepts respectively. The information gathered through the ethnomusicological study of Bachata and Merengue is condensed using the OAR model to yield sets of attributes and objects. Operations are conducted to test how these denoted concepts relate to one-another. Conclusions will be taken to be meaningful if results are in line with an intuitive understanding.

Operationalization of Concepts

$$C(Merengue) \cong C_M(A_M, O_M, R_M^c, R_M^i, R_M^o)$$

$$C_M \begin{cases} A_M = \left\{ \begin{array}{c} manic, glib, bourgeoise, counterpoint, tigueraje, guitar, accordion, guira \\ marimba, tambora, saxophone, trumpet, erotic, international, commercial \\ perico ripiao, dance, electric bass, social commentary, unifying, Afro-Dominican \\ European, Latin, Ensemble, brisk, nationality, modern, rustic, lower class, \\ call-and-response, drum rolls, improvisation, celebration, quisqueya, Dominican, \\ energetic, Cibao valley, Santo Domingo de los Caballeros, Yankee, salons, clubs, \\ Johnny Ventura, Luis Alberti, Nico Lora, Tono Arben, Wilfrido Vargas \\ Juan Luis Guerra, syncopation, arpeggios, Washington Heights, Trujillo \end{array} \right\} \\[2em] O_M = \left\{ \begin{array}{c} merengue tipico Cibaeno, merengue tipico moderno, orquesta merengue, pambiche \\ mangolina, paseo, jaleo, mambo, a lo maco, paso de empalizada, timbre \\ fast tempo, Dominican Republic, instrumentation, identity, immigration \end{array} \right\} \\[1em] R_M^c = O_M \times A_M \\ R_M^i \subseteq \Re \times C_M \\ R_M^o \subseteq C_M \times \Re \end{cases}$$

$$C(Bachata) \cong C_B(A_B, O_B, R_B^c, R_B^i, R_B^o)$$

$$C_B \begin{cases} A_M = \left\{ \begin{array}{c} Bitterness, love, masculinity, sexuality, urbanization, betrayal, lower class, \\ derogatory, concon, colmados, dance, guitar, maracas, electric acoustic, \\ marimba, bongo, tambora, romantic, serenade, commercial, international, ribald \\ innuendo, vulgar, chachivache, poverty, slums, Quisqueya, Dominican, \\ sensual, guira, syncopation, arpeggios, Washington Heights, Trujillo, Balaguer, \\ Latin, Aventura, Antony Santos, Jose Manuel Calderon, Juan Luis Guerra, \\ Luis Vargas, Romeo Santos \end{array} \right\} \\[1.5em] O_M = \left\{ \begin{array}{c} Double Entendre, Villa Miseria, Immigration, Instrumentation, \\ Bachata-merengue, Dominican republic, timbre, slow tempo, genre fusion, \\ censorship, canciones de amague \end{array} \right\} \\[1em] R_B^c = O_B \times A_B \\ R_B^i \subseteq \Re \times C_B \\ R_B^o \subseteq C_B \times \Re \end{cases}$$

Showing Relatedness

$$\{C_M \leftrightarrow C_B | A_M \cap A_B \neq \emptyset \vee R_M^i \cap (R_B^o)^{-1} \neq \emptyset \vee R_M^o \cap (R_B^1)^{-1}\}:$$

$A_M \cap A_B = guitar, guira, tambora, commercial, international, dominican, Quisqueya,$

$Juan Luis Guerra, lowerclass, syncopation, arpeggios, Washington Heights, Trujillo, latin,$

$marimba, dance \therefore A_M \cap A_B \neq \emptyset \Rightarrow C_M \leftrightarrow C_B \blacksquare$

Bachata and Merengue are related on a conceptual level. Comparisons can be performed.

Showing Similarity

$$C_M \sim C_B \cong \frac{|A_M \cap A_B|}{|A_M \cup A_B|}$$

1. $|A_M \cap A_B| =$

$|guitar, guira, tambora, commercial, international, dominican, Quisqueya,$

$Juan Luis Guerra, lowerclass, syncopation, arpeggios, Washington Heights, Trujillo, latin,$

$marimba, dance| = 16$

2. $|A_M \cup A_B| = |manic, glib, bourgeoise, counterpoint, tigueraje \dots Romeo Santos| = 52$

3. $\frac{|A_M \cap A_B|}{|A_M \cup A_B|} = \frac{16}{52} = .307$

The operationalized genres are 30.7% similar. 69.3% of the operationalized attributes are not equivalent. Better conceptual definitions could reveal more latent similarity.

Comparability Analysis

Definition: $x \leq y \text{ or } y \geq x.$

comparability is any set of relations in a partially ordered set such that . Unfortunately, since no attribute can be said to be 'greater' than another attribute in ethnomusicology, Merengue and Bachata are not directly comparable.

DISCUSSION & CONCLUSION

CA provides a systemic method for rigorously denoting concepts within a universe of discourse. In simple ethnomusicological applications, CA can establish relatedness between genres and proportions of attribute-based similarities.

While the applications of CA above might seem trivial, the ability to produce reliable representations of genre is important computationally. Operationalized concepts can be used to construct rigorous knowledge graphs, revealing unaddressed discursive gaps. Analysis can be facilitated. Broadly-accepted definitions could be shared between authors, and debates be rigorously denoted. Potentially, one could catalog their knowledge and combinatorically search for topics to explore, picking rather than computing different research possibilities.

This denotational paradigm is most useful when one has ample data. For example, characteristics of the sound itself could be substituted for the word attributes above. Machine learning could then be used to discriminate between genres and analyze elements of novel pieces of music. New subgenres could be identified within musical styles. Most excitingly, a myriad of graphical visualizations of sound could be made possible.

Denotational paradigms could potentially be used for modelling conceptual relations on spectral or co-spectral graphs. It is recommended that future studies with more resources at their disposal carry out serial atomizations of ethnomusicological concepts based on acoustic characteristics and perhaps pictures/videos of visual artefacts.

As this project was under a significant time and resource constraint, and as the aforementioned method had to be synthesized for a dedicated, limited application. This denotational mathematics method is flexible and can be adapted across the humanities to enable quantitative rigor. Although this study was unable to produce visualizations, extensions are strongly encouraged to attempt using this method to visualize discursive or textual material.

Ultimately, while the constraints of concept algebra demand a deep, atomized understanding of complex ethnomusicological concepts, they show promise—particularly if combined by an enterprising researcher with computational-systematic musicological methods. The CA method has added benefits in that it demands transparency and is ruthless in exposing narrative manipulation and misunderstanding. It demands that the analyst account for every step in their analytical process. The author encourages criticism of the concept algebra used above.

Finally, it should be noted that computer programs can be based off CA insights. This would potentially open the way for truly computational approaches to ethnomusicology, with myriad applications that leverage the full power of artificial intelligence. Under a more qualified hand, this method could generate interesting insights across traditionally discursive humanities, bridging the gap between mathematics and qualitative discourse.

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About the Author

Niazi Murataj is a senior at the University of North Carolina at Chapel Hill studying Business and Computer Science. He is interested in interdisciplinary modeling—specifically, in taking complex phenomena and making them computer-representable. After taking an ethnomusicology class as a general education requirement, Niazi identified a mapping between traditional musical genres and their respective cultures; he chose to create a formal schema to model musical genre because it was challenging.