

An impressionist painting of a woman in profile, wearing a white bonnet and a light blue dress, reading a book. The background is soft and painterly, with visible brushstrokes. The bottom left corner features a green, leafy plant.

The Owl

Vol. 10 | Spring 2020

Florida State University

Undergraduate Research Journal

Cover Inspired By:
**Remodeling Gender in
Nineteenth-Century Paris**
By Allison Marino

Featured Articles in This Issue:

**Prejudicial Processing in
Language Fluency,
Elementary Education in
Ancient Rome,
and more**

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THE OWL

THE FLORIDA STATE UNIVERSITY
UNDERGRADUATE RESEARCH JOURNAL



VOL. 10, No. 1
SPRING 2020

2019-2020 Editorial Board

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Letter from the Editor

Dear Reader,

In my four years as a undergraduate researcher at Florida State University, I have been exposed to a wide array of original and exemplary research conducted by my peers in almost all of the majors the university offers. As someone who grew up assuming research was confined to the bounds of a laboratory, complete with beakers and lab coats, I was inspired by the research I saw students doing in economics, modern languages, art, music, business, and more, as well as those in the hard sciences. Florida State does an excellent job of supporting research in all of these areas, fostering the development of credible and ethical researchers while they add to the knowledge of their fields. This edition of *The Owl* seeks to highlight that incredible diversity of research, with articles from the classics, political science, and physics, as well as creative works that include an honors thesis project from the film school (a first for *The Owl*). I hope that this fosters an appreciation among our readers for the many manifestations of research at the undergraduate level, and encourages student readers to seek out the areas that most interest them, if they have not already. Florida State has an impressive variety of ways to become involved in research as an undergraduate and *The Owl* is a showcase of the heights to which these opportunities can take motivated students. I applaud the authors of this edition on the work that lead them to this point, and I wish them the best as they continue to learn from these research projects and others.

I would especially like to thank this year's Associate Editors: Kristie Dick, Jose Martinez, Trystan Loustau, and Ashley Moses. Their insightful critiques of each submission and collective desire to see *The Owl* flourish are a large part of what made this year's edition as strong as it is. I am grateful for the opportunity to have worked with them and I look forward to seeing their continuing impact on the research in their respective fields.

In Vires, Artes, Mores,

Lauren Moran

Lauren Moran

Editor-in-Chief

ARTICLES

PREJUDICIAL PROCESSING: AN INVESTIGATION OF THE ROLE OF PREJUDICE AND BIAS ON THE FLUENCY EFFECT

Jacob Cryderman

Abstract

The present study examines the fluency effect and factors which may influence its prevalence. The fluency effect is a phenomenon first reported by Lev-Ari and Keysar (2010), which purports that people attribute less believability to those with accented speech as opposed to those with native accents, despite the content of speech being identical. The fluency effect is thought to be due to language processing efficiency alone, rather than to any influence outside of the language processing system. This claim, however, is untested. The present study first replicates the experiment conducted by Lev-Ari and Keysar (2010) where participants were asked to listen to trivia facts and indicate whether they seem true or false. Participants were then asked to complete measures for additional potential influencing factors. The additional factors of interest for this project are the prejudicial views and biases of the participants as measured by the Feeling Thermometer and the Implicit Association Test respectively. In contrast to earlier work, this study showed no evidence of a fluency effect. The study also showed no evidence that prejudices and biases affected the participants' responses to statements by different speakers.

People are constantly bombarded by speech. Communication is a fundamental aspect of human interaction and we must constantly make judgments on the information we hear. According to the cooperative principle that is thought to guide successful conversations in everyday life, individuals do not seek to provide false information in conversation (Grice, 1975). A result of this unspoken rule is that individuals will generally assume they are being told the truth. However, this trend begins to break down as statements seem to “not sound right,” or when a statement seems unlikely to be true due to content, origin or some other factor. This breakdown of the assumption of truth and the factors that lead to a sense of a statement not sounding correct is of principal interest in this study.

When the truthfulness of a statement is in doubt, individuals begin to rely on methods and cognitive processes other than assumption to ascertain the truth. One such process is known as the fluency effect (Lev-Ari and Keysar, 2010). The fluency effect refers to fluency of cognitive processing of a given stimulus leading to that stimulus being more or less believable. In general, all other factors being equal, individuals tend to rate stimuli they can better understand and more efficiently process as more representative of the truth. This effect is well evidenced by the work of Lev-Ari and Keysar (2010). In his work, it was found that people are more likely to believe speakers that are easier to understand (i.e. native speakers of the language) when compared to speakers with foreign or unfamiliar accents. This is largely attributed to the aforementioned fluency effect as the truthfulness is determined by language processing efficiency rather than more objective statement content analyses.

Interestingly, Lev-Ari and Keysar (2010) came to the conclusion that the fluency effect they found evidence for was entirely based on the efficiency of language processing. However, they generally did not test for the influence of other factors. There were some attempts to control for influencing factors but these attempts often did not go far enough to truly isolate the potential third-variable problems. One such factor of interest that is marginally addressed but not adequately tested is the role of differing backgrounds due to the importance of accents on the study, there seems to be a strong possibility that some of the ratings of truthfulness may be based on prejudicial views or biases held by the participants listening to the statements. It is

common knowledge that people are constantly influenced by personal biases and outright prejudices (Huntley, 2019; Gluszek prejudice on ratings of truth (Lev-Ari and Keysar, 2010). As the speakers are necessarily of & Dovidio; 2010, Anne-Sophie & Scott, 2010; Mai & Hoffman, 2014). Such influences are likely to affect language processing as well. The present project seeks to replicate the work of Lev-Ari and Keysar (2010) and additionally assess the role of prejudice and bias on the fluency effect.

Attitudes towards non-native accents have a quite large role in contemporary society as they often influence a number of aspects of behavior (Gluszek & Dovidio; 2010, Anne-Sophie & Scott, 2010; Mai & Hoffman, 2014) It is common to study these influences and their impact on employment and economics and it has been shown that these influences have quite negative results for those who speak with a non-standard accent. Accented speakers have been found to suffer in interviews and in general business and economic actions (Anne-Sophie & Scott, 2010; Mai & Hoffman, 2014). While these studies are comprehensive and serve to complete the objective they set out to complete, these studies often do not delve into underlying causes of negative attitudes towards out-groups, but rather assume their existence.

In addition to economic discrimination, people's attitudes towards non-native accented speakers may skew their worldviews away from rationality. Such an influence over one's perception of reality is of great concern to society as it serves to obfuscate objective truths and may lead to discriminatory practices, both in conscious and obvious ways and those that may be more subtle. Additionally, such accent effects as those described by within this project, whether prejudicially based or not, often lead to a sense of exclusion within foreign accented populations (Gluszek & Dovidio, 2010). As such, it is imperative that we seek greater understanding of this phenomenon so that we are better equipped to scientifically address the likely unavoidable consequences of bias in cognition and language processing.

Broadly, this study seeks to address the question of how bias and prejudice impact the fluency effect. We expect participants who show a higher rate of prejudice and bias will show a stronger fluency effect (that is, a larger difference in the assessment of statements by native and non-native speakers). This hypothesis is largely based upon

known effects of personal biases influencing other areas of cognition. Such effects are extensive, and it seems unlikely they should be absent from speech processing efforts (Huntley, 2019; Gluszek & Dovidio; 2010, Anne-Sophie & Scott, 2010; Mai & Hoffman, 2014).

Alternatively, the more traditionally understood cause of the fluency effect may be the cause of the results. The traditional view is that the fluency effect is based on mere capability of language processing rather than any other extra-linguistic factors. There is also mixed evidence that individuals are able to suppress personal biases against a certain group when audio is all that is present and it may be that people require a physical presence to fall within the negative trends of the fluency effect based on prejudice or biases (Wang, Arndt, Singh, Biernat, & Liu, 2012). It is this gap in research that this project hopes to fill.

In order to test between the language-processing-alone account and the language-processing-plus-prejudice account, this study measures prejudice and bias of participants and seeks to demonstrate what relationship these factors have with the fluency effect. The present study first aims to replicate the findings of Lev-Ari and Keysar (2010) and then it aims to assess the role of the covariates of prejudice and bias. This assessment of the relationships between these concepts will provide a part of the answer to the question of what influences different outside factors have upon the fluency effect.

Methods

In order to obtain this greater understanding and address the proposed question, this study first sought to replicate the work of Lev-Ari and Keysar (2010). Then, part of the conclusion drawn by previous researchers was to be challenged. Specifically, the current study was to challenge the assumption made by Lev-Ari and Keysar of the fluency effect being based on processing efficiency alone (2010). As mentioned previously, this study will examine the role of bias and prejudice on the fluency effect found in Lev-Ari and Keysar's work.

Participants

Participants were all recruited from a student population of a Southeastern university. Through this recruitment method, a sample size of 166 participants provided usable data. Compensation for participation was provided in the form of class credit. Though

initially led to believe the study focused upon intuition rather than prejudice or bias, all participants were informed on the risks associated with the study before undertaking any tasks related to data collection. Deception was utilized in order to prevent participants from artificially changing their responses in order to be perceived as less prejudicial. Participants' data was used only if they consented after they were informed of the deception during the debriefing. All participants completed the same survey with various counterbalanced variations.

Materials

All data was collected using an online survey created and distributed through the online program Qualtrics. This survey included all aspects of the study and was distributed exclusively online. The survey consisted of four separate sections.

The first section provided 48 trivia fact audio files sequentially to participants. These trivia facts were all read aloud by various speakers of differing accents. In total, there were six different speakers that recorded readings of the same trivia fact script. These speakers included two natively-accented speakers, one Irish, one English, one Spanish and one Moroccan accented speaker. These speakers were selected primarily due to availability. However, the foreign accents available conveniently were complimentary of one another. The Irish and English speakers served as strong and weak English-speaking western European respectively and due to the intertwined history of Spain and Morocco, the speakers from this region also served one another as strong and weak accents of similar type. These accent strengths allowed further analysis of the impact of accent strength on the fluency effect. Additionally, all speakers will be female in order to control for potential gender biases. It is certainly possible, if provided with a mixture of speakers of different sexes, for participants with a tendency for misogyny or misandry to allow those prejudices to guide their responses. For the purpose of this study, only prejudice and bias based on accent alone were of interest.

The second section of the survey was the Implicit Association Test portion in which participants completed the task that results in a D-score that serves as a numerical representation of bias for or against certain targets (Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. K. 1998; Greenwald *et al.* 2009). For this study, the target for

which bias was measured was American and Foreign. The third section of the survey consisted of the Feeling thermometer, a tool for measuring explicit prejudices (Axt, 2017). While it may seem counter-productive to use as explicit a measure as the Feeling Thermometer in light of the project's deception used to limit changing answers to those more socially acceptable, the measure possesses quite robust validity (Alwin, D. F. 2007). Additionally, the deception's objective is to prevent alteration of one's true and false ratings, which have already been completed by this point in the project.

The fourth and final portion of the survey was a series of demographic measures. Age, gender, race, ethnicity and political leanings were collected. These demographics were used in various exploratory analyses but no effects pertaining to any demographic were found.

Procedure

Using the survey described previously, participants were first asked to listen to 48 trivia facts uttered by the various different speakers and provide an assessment of if the fact heard was true or false. All trivia facts were sourced from various online resources and confirmed to be factual through separate sources as well. An example of such a fact is "Giraffes have the highest blood pressure of any animal." All facts used were similarly unusual. Using such obscure facts was done in order to minimize the effect of any prior knowledge held by participants. In order to induce the aforementioned breakdown of the assumption of truth of information provided, this study was initially presented to participants as a test of intuition. These misleading instructions inform the participant that much of what will be presented to them will be questionable information.

Participants heard a random speaker for each fact but no fact was repeated for the same participant. Participants' error rates were of interest and were recorded as a ratio for each speaker, for total native and total foreign speakers, and for no accent, light accented and heavy accented speakers. The specific country of origin for each accented speaker will also be noted as we will establish whether a participant possesses a negative attitude toward the speaker's origin; there is also some evidence that unfamiliarity with an accent may significantly influence the listener's response to it, even in the absence of prejudice (Braun, Llamas, Watt, French, & Robertson, 2018). Participants were then asked to complete an Implicit Association Test (IAT) to measure

implicit biases and a variation of the Feeling Thermometer questionnaire to assess the presence of direct prejudicial views held by the participant (Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. K. 1998; Greenwald *et al.* 2009; Alwin, D. F. 2007). The IAT was programmed and analyzed utilizing the tools provided by Carpenter, et al. (2018). These numerical measures of prejudice and bias were then compared to the rate at which the participant scored the facts as true or false; the objective of this comparison was to determine what relationship exists between biases and prejudices and the rating of truth for the statements. Such a relationship would provide the researchers with an answer to the question of interest in that it will show if the separate concepts, biases and prejudice and the fluency effect, are related to one another in a meaningful way.

Results

Analysis One - Accent Strength

Table 1 - Descriptive Statistics

Speaker Accent Strength	Mean Error Rate	Standard Deviation	N
Native	0.408	0.203	166
Light	0.399	0.202	166
Heavy	0.415	0.208	166

Table 2 - Categorical Accent Comparisons

Accent Strengths Comparison	Mean Difference	P - Value
Native vs. Light	0.008	1
Native vs. Heavy	-0.008	1
Light vs. Heavy	-0.16	0.835

The average accuracy for participants was analyzed with an ANCOVA that included Accent strength (native, light, and heavy) as a fixed factor, and Prejudice and Bias as covariates. There was no difference in accuracy for the truth ratings across Accent strength $F(5, 166) = 1.698$, $p = 0.185$. That is, we did not find evidence for a fluency effect in our data. Prejudice on its own did not serve as a predictor to a significant degree, $F(5, 160) = 0.032$, $p = 0.857$. Bias on its own also did not serve as a predictor to a significant degree, $F(5, 160) = 1.482$, $p = 0.225$. Neither of these variables interacted with accent strength, $F(5, 160) = 1.126$, $p = 0.325$ for bias and $F(5, 160) = 0.339$, $p = 0.713$ for prejudice.

Analysis Two - Individual Speakers

Table 3 - Descriptive Statistics

Speaker	Mean Error Rate	Standard Deviation	N
Native 1	0.395	0.201	166
Native 2	0.422	0.205	166
English	0.402	0.193	166
Irish	0.382	0.209	166
Moroccan	0.396	0.211	166
Spanish	0.448	0.207	166

We performed an additional ANCOVA with Speaker (the 6 individual speakers) as a fixed factor and Prejudice and Bias as covariates. Although we did not see an effect across accent types in the first analysis, we were interested in assessing whether there were differences across individual speakers. The effect of Speaker was marginally significant, $F(5, 160) = 1.989$, $p\text{-value} = 0.078$. Post-hoc tests (Bonferroni corrected) indicated one difference in responses to individual speakers, namely the difference between the Irish-accented speaker and the Spanish-accented speaker ($p\text{-value} = 0.028$). As before, the effects of Prejudice and Bias were not significant. Prejudice on its own did not serve as a predictor to a significant degree, $F(5, 160) = 0.075$, $p = 0.784$. Bias on its own also did not serve as a predictor to a significant degree, $F(5, 160) = 1.273$, $p = 0.261$, nor were the interactions of these variables with Speaker significant, $F(5, 160) = 0.58$, $p = 0.715$ for bias and $F(5, 160) = 0.708$, $p = 0.617$ for prejudice.

Discussion

It seems there is no conclusive support for the existence of the fluency effect in the population studied in this project. The lack of significant differences between truth ratings for Native-accented speakers and foreign-accented speakers in general offer strong support for this claim, as does the fact that no individual speaker's truth ratings differed significantly from either of the two native-accented truth ratings. This lack of evidence for the fluency effect may be considered a rather positive result however, as it may, in general, be that people are able to suspend their prejudicial views or biased attitudes when judging objective reality.

Though it is potentially a positive outcome for societal interac-

tions, the lack of support for the fluency effect in the studied population is not consistent with expectations. The researchers believed the fluency effect to be valid and as such planned to do further analyses to find cognitive origins of the effect. The proposed influencing factors of prejudice and bias did not have an influence on truth ratings, but this is not surprising considering the absence of the fluency effect overall. As such, little can be concluded about these variables. From the data gathered, individual differences other than the presence or absence of an accent among speakers seem the most likely explanation for the few significant results found.

Possible explanations for the lack of support for the previous work conducted by Lev-Ari and Keysar (2010) may arise from certain methodological differences between the current study and the earlier studies. Of the most significant of these differences is the relatively small sample size of the previous project. Lev-Ari and Keysar (2010) conducted two separate experiments, of varying effectiveness, one of which had 30 participants and the other had 27, leading to a total of 57 participants. The present study's larger sample size of 166 may give a more accurate estimate of the effect that accents have on truth ratings and may be less likely to be a result of chance. Additionally, as alluded to previously, 30 of the previous study's data points may be of questionable validity. One of the two experiments of Lev-Ari and Keysar (2010) included a sort of priming as participants were told at the start of the experiment that it is often difficult to understand foreign accents. This may have primed the participants to perform worse as they possessed expectations for the outcome. Priming is well established to be present in a number of cognitive functions and language Processing is unlikely to be an exception (Bargh and Chartrand, 2000). This could potentially result in only 27 participants' data being valid as evidence for the fluency effect alone, furthering the previous study's problem of having a small sample size.

Due to the inconclusive nature of this project and its role in contradicting other previously established work, further study is necessary in order to ascertain the reality of the fluency effect. The effect found in previous work may be more a result of individual differences among the speakers tested rather than their accents alone. Alternatively, it may be that the previous project utilized much more heavily accented speakers than the present study incorporated. Though this project recruited speakers that had been living in the

United States for only a short period of time and with quite strong accents, the delineation between heavy and light accents is debatable. Additionally, if further research does provide support for the fluency effect in other populations, a revisiting of the impact of prejudice and bias would be warranted. Such factors being influential could not be ruled out by this study so their importance remains a possibility.

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A CASE FOR A STANDARD MATH EDUCATION IN ANCIENT ROME

Luis Sanchez

Abstract

Although overshadowed in the ancient Roman sources by the importance given to grammar and literature in a child's school curriculum, secondary instructors of rhetoric and philosophy frequently required their pupils to have a certain level of numerical familiarity. This requirement was demonstrated by Quintilian, who believed that mathematics were "essential not only to the orator, but to anyone who has had even a basic education" (Quint. Inst. 1.10.35). This study investigates what comprised this basic math education, and how, why, and for whom this curriculum was implemented across the unregulated educational institutions of late republican and imperial ancient Rome. Modern scholarly discussion on mathematics in early Roman education is limited, as the ancient sources have left us only fleeting mentions of math in the classroom or in practice. Through analysis of these references, widely scattered throughout ancient literature, I construct a probable mathematical lesson plan to determine what arithmetical operations and skills, such as rationality and finger reckoning, were expected of Roman children to become numerically competent adults. These texts not only provide glimpses into the Roman classroom and the teaching methods within it, but also allow us to explore ancient authors' varied attitudes toward math and educational institutions.

Modern scholarly discussion nearly unanimously agrees that primary education in ancient Rome was more or less the same for all who were able to receive one, consisting of grammar, literature, and arithmetic (Carrier, 2016; Cuomo, 2000; Rawson, 1985). Though the Latin sources are dominated by authors who exalted the language arts above all others, many secondary instructors required their students to have a basic mathematical competency. This requirement is demonstrated by Quintilian, an orator and educator from the early Roman Empire, who believed the youth should have this arithmetical foundation “before being handed over to the teacher of rhetoric” (Quint. Inst. 1.10.1). Despite the scholarly agreement, the question of what the Romans considered this “baseline” mathematical ability, and how it was determined and achieved, is yet to be answered. The delay in modern attempts to establish this common Roman numeracy, or familiarity with numbers and mathematics, can be attributed to the challenges presented in the unregulated and socially exclusive nature of ancient education. As a consequence of this lack of legislated uniformity, there is lack of dedicated sources on teaching or learning math. In the ancient literature, references to mathematics in educational contexts and in practice are few and fleeting, but through their examination, this paper explores the innerworkings of the Roman “classroom,” educational system, math curriculum, and sentiment toward numeracy. My research reveals that there indeed was a relatively standard elementary math education in late republican and imperial ancient Rome, shaped by social expectations of numeracy and the necessity of effectively handling finances.

Before discussing of what this standard elementary math education comprised, I will begin by examining for whom this numeracy could have possibly been called “standard.” The most educated demographic in ancient Rome was the aristocracy, for this class had the freedom and time to pursue learning (Rawson, 1985), and the means to pay for it. While the vast majority of slaves were not, a considerable number were already educated and made tutors to the aristocracy or chosen to be educated by their owners for their own interests. These educated slaves were capable of fetching higher prices and were thought to be worthy of handling tasks that required more scrutiny and trust (Carrier, 2016). By no means barred from education, aristocratic women were usually given a schooling, but

far less often and not to the same extent as their male counterparts, as they were relegated to household matters more often than not. Practicing any education they did receive was especially difficult for women, however, because most professions and offices were restricted to them on the basis of tradition or social stigma (Carrier, 2016).

Considering these factors, the person who received a math education, or any education at all, was no average Roman. This individual would have likely belonged to one of the smallest demographics in ancient Rome: that of freeborn, aristocratic, male citizens. The exclusivity of education can be visualized in the estimate that fewer than 15% of the population was able to read in even the most literate cities of the early Roman Empire (Harris, 1989). The average Roman who qualified to receive an education did not accurately reflect the greater part of the population, and this fact must be considered in investigating how a single subject within education could be called “standard.” These math lessons were given to such a small fraction of the populace, and these lessons likely were not standard either.

Education of children in ancient Rome traditionally took place with tutors at home or in small, local schools called *ludi*. Rome did not have state-sponsored schools offering state-regulated programs in the same sense that they exist today. These Roman “public schools” were few, could only be found in larger cities, and did not have a regular curriculum (Carrier, 2016). The quality of these schools is represented negatively in literature, and they were usually deemed inferior to a traditional private education. In a letter, Imperial Roman author and magistrate Pliny the Younger recounts his encounter with a father and his son, who was educated away in Mediolanum, the home of one of these public schools (Plin. Ep. 4.13.3). He begged the father to have his son taught in their native city with a local tutor, and Pliny felt so passionate as to even offer to help pay for the boy’s education, pointing out the low quality and “evil practices” taking place “where teachers’ salaries are paid from public funds.” Even Emperor Marcus Aurelius, in his *Meditations*, denounces public schools, noting the importance of spending money “to enjoy good teachers at home” (M. Aur. Med. 1.4). The bias must be acknowledged, however, as these excerpts, and nearly all of ancient literature, come down to us from privately educated aristocrats. Given the reputation state-sponsored schools had in literature, we must wonder what appeal they had in

Rome. Their operation, despite their infamy, suggests they were likely less expensive than private tutors. Whether Roman children were educated by family-funded tutors or, more rarely, these state-subsidized institutions, the education they received was not regulated by any legislation. The search for a standard elementary math education would have to be a question of what expectations of numeracy were placed on children, and what they had to master to be functioning, mathematically-competent adults.

A few Roman authors have specifically written on the importance of having a mathematical education, though exclusively as smaller topics within broader treatises. Although these authors do not specifically list what mathematical operations must be known to the educated Roman, they do shed light on sentiment toward mathematical capability. Examining these works allowed me to commence my argument for the existence of an expected, and possibly standard, numeracy. In *De Oratore*, Cicero, statesman and writer of the late Roman Republic, discusses the importance of an orator's ability to speak on any subject, including mathematics (Cic. De or. 2.66). He looks fondly upon the great orators of history, such as Hippias of Elis, who claimed that there was "not a single fact with which he was unacquainted," and that he was familiar with each of the vocational and liberal arts, including geometry (Cic. De or. 3.127). While Cicero romanticizes and lauds the well-rounded knowledge of the perfect orator in *De Oratore*, Quintilian actually discusses the pragmatic benefits of numeracy to a speaker in *Institutio Oratoria*. He also tells us that there indeed was a "public opinion" on mathematics in education, though he may disagree with it. He introduces the topic of the orator's math education with his defense of *geometria*, which, given the content of the rest of the topic, is to be safely understood as meaning mathematics in general.

As for geometry, it can be confessed that some parts are useful to be had in youth, for it exercises the mind, sharpens the wits, and generates quickness of perception. But it is estimated that the benefits come not, as with other arts, when it has been grasped, but only during the learning process. This is the common (*vulgaris*) opinion. It is not without reason that great men have expended enormous effort on this science. (Quint. Inst. 1.10.34)

In this passage, with the use of the word “*vulgaris*,” Quintilian disagrees with what he claims to be the “common” or “uneducated” opinion, that the mathematical arts are solely useful for the development of children in their formative years. The fact that this sentiment, with which he opposes, concerning the youth’s math education can be called “common” strengthens the case that there indeed was an elementary math curriculum, though its content is still to be examined. Quintilian asserts that the benefits of mathematics transcend the education of children when he says, “Knowledge of numbers is essential not only to the orator, but to anyone who has had even a basic education. It is indeed very frequently involved in actual cases” (Quint. *Inst.* 1.10.35). Here, Quintilian further reinforces the existence of a basic education and the meritorious place mathematics has within it, as well as the fact that math was useful to educated Romans past childhood and outside of the classroom, such as in the court cases he describes. This supports the argument proposed on the existence of social expectations of numeracy placed on the educated, but leaves us to wonder in what mathematical skills and operations these expectations culminated.

Next, through analysis of references in literature, we can distill what a standard elementary math education comprised of in Rome. The references are nearly always made in mere passing, which could suggest indifference on the author’s part or, more likely, the ubiquity of certain mathematical lessons in education and what could make up a basic numerical knowledge among the educated. The foremost skill would need to be the ability to recognize numbers and manipulate them in addition and subtraction. An instance of this elementary lesson is preserved for us in Augustine’s *Confessiones*, where the late imperial theologian painfully recalls the addition tables he had to recite aloud. He writes of a song that sounds similar to what would be sung in primary schools today: “one plus one is two, two plus two is four” (August. *Conf.* 1.22). He calls it an “*odiosa cantio*,” revealing his disdain for what could have been either his least favorite subject in youth or what might have been his annoyance at what had to be recited too often. The ability to count needs no justification to be part of a standard elementary math education, but through this recollection of Augustine, we catch a small glimpse of what the Roman classroom was like. Another peak into the classroom environment, and the growing complexity of mathematical education among what

could be considered to be older students, is given to us in Horace's *Ars Poetica*.

Our Roman boys, by a long sum, learn in childhood to divide the as into a hundred parts.

'Let the son of Albinus answer. If from five-twelfths one ounce be taken, what remains? You could have already answered.'

'A third.'

'Good! you will be able to look after your means (rem). An ounce is added; what's the result?'

'A half.' (Hor. Ars P. 325-30)

In this passage, the early imperial poet Horace does much more than simply share his comments on Roman greed. With these few lines, rationality emerges in the mathematical curriculum, and it appears that Romans learn their fractions through their units of currency. He mentions that this skill is learned in childhood, to say that avarice is inculcated early in a Roman's life, but he also elucidates where to put rationality on our educational timeline. The imagined teacher calls upon "the son of Albinus" to answer the question, which further reinforces the oral aspect of Roman education (Cuomo, 2000), some of which we already saw with Augustine. Upon answering the question correctly, the student is praised by his teacher and assured that he will be able to manage his "means," which could be translated from the Latin as "things," "affairs," "matters," and even "property." With this student's due praise, we are beginning to see that elementary math education in Rome had a practical nature and had goals in asset management. The expectation of being able to count, add, subtract, and divide would translate into the ability to transact and change money, and "look after one's means." I argue that this expectation of competently working with money and other assets, in turn, would shape the mathematical lesson plan that would end up being relatively standard throughout Rome. The elementary math curriculum does not stop there, however. Though the aristocracy may have had the time to dive into the more theoretical end of mathematics, the pragmatic nature of primary school lessons makes way for a skill that I contend was known to most educated people in Rome.

The skill of counting and calculating on fingers, known as finger

reckoning, is widely represented in Roman literature, spanning across letters, treatises, poetry, and even the theater. Roman finger reckoning was quite sophisticated, as seen from the operations described, but the ancient sources did not leave behind any complete sets of instructions to their methods (Williams & Williams, 1995). Some authors wrote, in quick references, how to gesture certain numbers, but the lack of a complete manual despite the skill's presence in literature again attests to both the strong oral aspect of Roman education and what could have been the ubiquitous nature of finger reckoning in math education. The impossibility of knowing how much of this skill was taught to children by their parents at home must also be considered. Examining manuscripts from countries once under Roman influence, however, yields promising results. Medieval manuals on number gesturing do exist from countries as distant as England and Greece, however, and their agreement on method has convinced modern scholars of the likelihood of a correlation between the medieval and Roman approaches to the skill (Turner, 1951), implying there may have once been a standard Roman method.

References to finger reckoning in Roman literature are usually made in passing, such as Palaestrio's "calculating" right hand in Plautus' *Miles Gloriosus* (Plaut. Mil. 1.203-8), and the "fingers by which we are wont to count," in Ovid's *Fasti* (Ov. Fast. 3.123). In his defense of mathematical capability in *Institutio Oratore*, Quintilian mentions the importance of possessing a mastery of finger reckoning in saying, "There the speaker is thought an ignoramus (*iudicatur indoctus*), I will not say if he hesitates in adding up, but if he contradicts his calculations by shaky and inappropriate movements with his fingers" (Quint. Inst. 1.10.35). Quintilian reveals what would be the humiliation of an educated Roman that is unable to perform what appears to be a common skill. This imagined person giving a speech would likely be surrounded by some of the most influential people of ancient Rome, who would have been able to afford an education. Quintilian plainly says this person would be considered "unlearned," convincingly implying this commonly held education among the audience must have contained finger reckoning.

Literary presence aside, the capabilities of Roman finger reckoning are also quite impressive. In *Historia Naturalis*, Pliny describes a statue of Janus gesturing 355 with its hands (Plin. HN 34.33-4), demonstrating the skill's quantitative capacity, which starkly con-

trasts with the limits of the average, “modern” fingers. It is also worth mentioning that the medieval sources on finger reckoning, which are likely similar to the Roman style, attest to the ability to count up to 9999 (Turner, 1951). Arithmetical operations were also possible on the educated Roman’s fingers, and one of the most popular examples can be found in a letter from Cicero to Atticus, his friend and fellow equestrian class aristocrat (Cic. Att. 5.21.12-13). In it, Cicero relates the story of a disagreement he recently had with someone concerning the difference between a simple and compounding interest, and how Atticus, while reading the letter, ought to already know the answer, “knowing his fingers.” It cannot be known if calculating percentages with fingers would have been too advanced to be in an elementary math curriculum, and if Atticus learned the operation later in life, but it is interesting to see what this skill was capable of anyway, especially while reading a letter. How often finger reckoning is mentioned in literature, however, cannot be ignored. On account of this literary presence, how pragmatic it was to be familiar with the skill, and how embarrassing it was for an educated person to fumble at it, I propose finger reckoning had its place in Rome’s standard elementary math education and a certain degree of its mastery was expected of the educated.

In conclusion, elementary math education in ancient Rome can indeed be called standard, but only amongst the few fortunate enough to receive it. It may never be known to what extent mathematics were taught to children by their parents at home, but a pragmatic math curriculum can be seen to have existed in Rome’s unregulated educational systems. It was observed that the primary purpose of elementary math education in ancient Rome was for the practical skill of effectively handling money, which would have shaped mathematical lesson plans throughout the late republic and empire. Found throughout the literature, the expectation of numeracy placed upon the educated demographics of Rome further establish the existence of this standard math education. Just as there are today, different degrees of numerical expertise could have been found within each individual in ancient Rome (Cuomo, 2012), determined by his or her education, profession, and interests. Very few Romans continued past primary education, as Diocletian’s 301 CE Edict on Maximum Prices tells us secondary instructors could charge up to four times more than their primary counterparts (Car-

rier, 2016), making it all the more interesting to examine in what a “basic” math education culminated and what degree of math competency was shared by the majority of the educated in Rome.

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OBSERVABLES OF THE THREE BODY COULOMB PROBLEM

Shae Machlus

Introduction

Determining the behavior of a system of three interacting bodies is a problem made important by its application to a variety of physical systems. Using the Coulomb potential energy as the means of interaction between the bodies is particularly interesting for the following reasons.

- The Coulomb three body problem is the simplest three body system, and such calculations are benchmark results in atomic physics. Specifically, the helium atom is the simplest atom that can be solved numerically, and is of great interest to those testing and developing numerical techniques.
- The Coulomb potential energy decays with distance identically to the gravitational potential energy. The code developed in this work can easily have the potential energy altered to work on a gravitational problem or incorporate relativistic effects.
- The development of high precision calculations is crucial for comparison to experimental data. For example, an experimentalist comparing a system of three particles to the same system of three antiparticles will want high precision calculations of their energies when testing to see if the two systems are asymmetrical.

(continued on following page)

The further pursuit of this problem and of many body physics in general is encouraged by the far-reaching applicability of the subject. For instance, certain planetary systems are best simulated using three body dynamics. In the ν Andromedae planetary system (two planets and a central star), there was a problem of justifying surprisingly large orbital eccentricities of the two planets; the large planet masses and small semimajor axes of the orbits made the system impossible to study using classical perturbation methods. This three body problem was treated numerically and insight about the initial conditions of the system was gained by doing so [1].

In nuclear physics, a deuteron stripping interaction can be understood through three body formalism. Deuteron stripping is when a deuteron is fired at a target nucleus—the deuteron splits and only the proton of the deuteron continues past the target nucleus, and it moves in roughly the original direction with roughly its original speed. Such interactions are useful probes of nuclear structure. Because the deuteron is weakly bound, its proton, neutron, and the target nucleus briefly form a three body system which, when properly understood, yields a more detailed view of the deuteron stripping process [2].

Three body physics is even general enough to be applied to holes and electrons in the field of condensed matter physics. Early transition elements are known to demonstrate an unusually energetic Auger spectrum which was not well understood. Auger electron spectroscopy is an experimental technique used to study the surfaces of materials. In [3], Green's function was used to develop a three body description of two holes and one electron in early transition elements, and this mathematical formulation effectively described the Auger spectrum phenomena.

In industry, quantum optical spectroscopy is a technique that excites and probes quantum systems like semiconductors and quantum dots using light. This technique is sensitive to quantum mechanical energy fluctuations, which are described by many body systems in excited matter. Such systems have been found to operate under the principles of classical chaos [4]. Understanding the interaction of the particles in the excited matter is necessary to make use of this novel spectroscopic tool. Thus for the benefit of both industry and academia, the study of the three body problem (and many body

problems in general) is well motivated.

Theoretical Background

Choice of Units

To limit our discussion to bound states, we consider three body systems where particles 1 and 2 are of the same charge, and particle 3 is oppositely charged (otherwise they would all mutually repel). Additionally, we require $m_1 \geq m_2$. There is no loss of generality in doing this since the labels m_1 and m_2 are arbitrary. It immediately follows that the reduced mass $\mu_{13} \geq \mu_{23}$. In this work, energy is measured in units of $\mu_{13} c^2 \alpha^2$ where α is the fine structure constant and c is the speed of light. The specific motivation for this choice is illustrated in [5]. To reduce the complexity of calculations, Hartree units are used, where $\hbar = k = a_o = me = 1$ and $c = 1/\alpha$. To recover units of energy, eV, once the calculation is complete, one must simply multiply the final value by the standard values of c_2 and α_2 , and also by μ_{13} , the reduced mass being scaled in the problem. Additionally, because $a_o = 1$ all distances r and radii R are implemented as multiples of a_o . The remainder of this work uses the Hartree unit convention.

Degrees of Freedom

In general, there are $3N$ degrees of freedom for an N body system corresponding to the 3 spatial dimensions each particle may travel in. However, moving to the center of mass reference frame, we can eliminate three of those coordinates by moving to the center of mass frame. In the absence of external forces, the center of mass moves with constant velocity and thus its frame is inertial. Moving to this frame, we consider the motion of two relative coordinate particles which totally describe the three body system.

We baptize the inter-particle distances as r_{12} , r_{23} , and r_{13} . The angular orientation of the plane is described by the Euler angles α , β , and γ . The wave function can therefore be expressed as a product sum of Wigner- D functions and radial functions Φ . The Wigner- D functions, which describe the angular orientation of the wave function, necessarily depend on the quantum numbers L and M .

$$\Psi_{LM} = \sum_K D_{MK}^{L*}(\alpha, \beta, \gamma) \Phi_K(r_{12}, r_{23}, r_{13}) \quad (1)$$

Further discussion of this angular separation is covered in [6, 7, 8]. In this work we are exclusively interested S -wave states, where $L = 0$ and therefore $M = 0$. Since $D\%_0 = 1$, the wave function is solely a function of the triangular coordinates.

Choice of Coordinates

Considering the Cartesian vectors r_{12} and r_{13} , we calculate the volume element in terms of their lengths and the angle between them, θ . In spherical coordinates, we expect a factor of $16\pi^2$, but pull out a factor of 2 in the form of the θ integral.

$$\int d^3r_{12}d^3r_{13} = 8\pi^2 \int r_{12}^2 dr_{12} \int r_{13}^2 dr_{13} \int_0^\pi \sin \theta d\theta \quad (2)$$

Since r_{12} , r_{23} , and r_{13} are the sides of a triangle, we apply the Law of Cosines to find an expression for r_{23} .

$$r_{23}^2 = r_{13}^2 + r_{12}^2 - 2r_{13}r_{12} \cos \theta \quad (3)$$

Which yields

$$\sin \theta d\theta = \frac{r_{23}}{r_{12}r_{13}} dr_{23} \quad (4)$$

Substituting this into Eq. 2,

$$\int d^3r_{12}d^3r_{13} = \int dr_{12} \int dr_{13} \int dr_{23} 8\pi^2 r_{12}r_{13}r_{23} \quad (5)$$

Which is precisely the Jacobian we desired (a function of only triangular coordinates). Annoyingly, the variables of integration for this Jacobian are determined by the satisfaction of the triangular condition.

$$|r_{12} - r_{23}| \leq r_{13} \leq r_{12} + r_{23} \quad (6)$$

However, in this problem we transform our coordinates to perimetric coordinates.

$$u = a(r_{12} + r_{23} - r_{13}) \quad (7)$$

$$v = b(r_{12} + r_{13} - r_{23}) \quad (8)$$

$$w = c(r_{13} + r_{23} - r_{12}) \quad (9)$$

The spatial coordinates are u, v , and w , and a, b , and c are scaling factors that may be determined from minimization.

These coordinates have no such triangular condition they must satisfy, and they have been praised for their ability to treat the three-body problem more analytically than hyperspherical coordinates [9, 10]. Hyperspherical coordinates arise from separating the 6 Jacobi coordinates into a hyperradial variable and 5 hyperangular variables. While Jacobi coordinates are necessary precursors to defining hyperspherical coordinates, they are not necessary in defining perimetric coordinates.

Perimetric coordinates are particularly useful for this problem since we are able to associate each of the coordinates u , v , and w with each of the three particles. We treat u and v the same by scaling them by the same parameter δ . This is motivated by the fact that w is unique in that the negative term r_{12} corresponds to the distance between the two electrons. In u and v the negative distances are both between electrons and the proton. w is thus given a different scaling.

$$a = b = \delta \quad (10)$$

$$c = \delta\lambda \quad (11)$$

This approach reduces our minimization problem to only 2 variables, and has been established as an effective technique in [5, 11]. To find the perimetric Jacobian, we use the inverse coordinate transformations.

$$r_{12} = \frac{1}{2a}u + \frac{1}{2b}v \quad (12)$$

$$r_{23} = \frac{1}{2a}u + \frac{1}{2c}w \quad (13)$$

$$r_{13} = \frac{1}{2b}v + \frac{1}{2c}w \quad (14)$$

The Jacobian in perimetric coordinates is now immediate.

$$8\pi^2 r_{12} r_{23} r_{13} dr_{12} dr_{23} dr_{13} = \pi^2 \frac{(av + bu)(aw + cu)(bw + cv)}{4a^3 b^3 c^3} du dv dw \quad (15)$$

Since this integral appears on both sides of Schrödinger's equation (in the calculation of the Hamiltonian matrix elements as well as the normalization kernel matrix elements), the code used in [5] "cancels" the constant prefactors (except 2). What results is $\hat{\tau}$.

$$\hat{\tau} = 2(u+v)(\lambda u+w)(\lambda v+w)dudvdw \quad (16)$$

However, in this paper we will use the full Jacobian τ , since we want to prioritize clarity over computational efficiency.

$$\tau = \pi^2 \frac{(av+bu)(aw+cu)(bw+cv)}{4a^3b^3c^3} \quad (17)$$

Variational Approach

There are many methods one can take to solve three body problem. One may discretize space and calculate the matrix elements of the Hamiltonian on a mesh using Lagrange functions [12]. Alternatively, one may solve Faddeev-Yakubovsky differential equations, which involve solving coupled equations of two-body problems to determine the behavior of three bodies [13]. In this work we make use of the variational approach. The simplicity and generality of this approach as well as its demonstrated success [5, 11, 14, 15] is what made it attractive for this work.

Choice of Basis & Symmetry

Inspired by the success of [5, 11], we write our wave function as a linear combination of Laguerre polynomial products with an exponential decay factor. The properties of the Laguerre polynomials that make them useful, specifically their orthogonality and simple recursive formula, are discussed in [16]. The fact that they are also the solution to the two body problem makes them a natural choice for a wave function basis.

$$\psi = e^{-\frac{1}{2}(u+v+w)} \sum_{i,j,k=0}^{\Omega} \alpha_{ijk} L_i(u) L_j(v) L_k(w) \quad (18)$$

$L_i(u)$ is a Laguerre polynomial of u of order i , α_{ijk} is a coefficient of the eigenvector of the three body system retrieved from the code in [5]. Let Ω be the maximum value of the sum of the orders of the products of Laguerre polynomials, determined by what is computationally desirable. The orders of the Laguerre polynomials increase according to Table 1 for $\Omega = 2$.

Basis State Number	Ω	i	j	k
1	0	0	0	0
2	1	0	1	0
3	1	0	0	1
4	2	1	1	0
5	2	0	2	0
6	2	0	1	1
7	2	0	0	2

Table 1: i, j , and k are the orders of the Laguerre polynomial whose product forms a basis state for the, eigenvectors. Ω is the maximum sum of these values, which we terminate at 2. i and j , corresponding to the two electrons, are symmetric since they are identical particles.

Note that we are invoking symmetry here. Since electrons are spin- $1/2$ fermions, their wave function is antisymmetric by the Pauli exclusion principle. Since the anti-symmetry is automatically accounted for by the Pauli principle, the spatial solution must be symmetric to ensure the full wave function is anti-symmetric (since an anti-symmetric object multiplied by a symmetric object is anti-symmetric). Here i and j correspond to the order of the Laguerre polynomial that represents the spatial function of the electrons. Hence, in Table 1 we do not consider $i = 0, j = 1, k = 0$ and $i = 1, j = 0, k = 0$ to be “different” states since electrons are identical particles. The nucleus is a different particle than an electron, so it is not included in a discussion of symmetry.

Normalization kernel

While the Laguerre polynomial products have their advantages, a disadvantage is that they are not orthonormal. Consider for instance a basis set of isolated Laguerre polynomials (not products of them). The inner product is as follows.

$$\int_0^\infty L_n(x)L_m(x)e^{-x}dx = \delta_{n,m} \quad (19)$$

That is, they are orthonormal under the weight e^{-x} . Constructing a matrix of overlap of these basis states is simply the identity map.

For a non-orthogonal basis, off-diagonal elements of this matrix would be nonzero. For a non-normalized basis matrix elements will take values other than 1. In general the matrix of overlap of a set of real basis functions will be symmetric and have arbitrary matrix elements. Such is the case of using a basis of products of Laguerre polynomials.

Using the Jacobian of perimetric coordinates and the Laguerre polynomial product basis function, each matrix element of the matrix of overlap (normalization) is computed in the following way. Letting

$$\phi_n = \text{basis state } n \text{ from Table 1} \quad (20)$$

We have that

$$N_{nm} = \int_0^\infty du \int_0^\infty dv \int_0^\infty dw [e^{-(u+v+w)} \phi_n \phi_m \tau] \quad (21)$$

However, to ensure that the symmetry of identical particles (electrons, in the case of the Helium atom) is properly represented we construct the matrix elements in the following way: if orders of the Laguerre polynomials corresponding to the identical particles in ϕ_n and/or ϕ_m are not equal, for instance, in ϕ_2 ($i = 0, j = 1, k = 0$), we symmetrize ϕ_n and/or ϕ_m . For instance, instead of using a single product of Laguerre polynomials for ϕ_2 , we use

$$\tilde{\phi}_2 = L_0(u)L_1(v)L_0(w) + L_1(u)L_0(v)L_0(w) \quad (22)$$

The constructed matrix is the metric of the function space: the eigenvector retrieved from the code in [5] $|\psi\rangle$ is normalized such that $\langle\psi|N|\psi\rangle = 1$.

Generalized Eigenvalue Problem

Consider the 2x2 generalized eigenvalue problem. It is generalized in the sense of using a non-orthonormal basis: N is not the identity matrix as it usually is taken to be when solving problems in quantum mechanics. Though the actual eigenvalue problem is solved using a 7x7 matrix, the process presented here is not dependent on matrix dimensionality.

$$H\psi = EN\psi \quad (23)$$

Where H is the Hamiltonian matrix

$$H = \begin{pmatrix} \langle\psi_1|H|\psi_1\rangle & \langle\psi_1|H|\psi_2\rangle \\ \langle\psi_2|H|\psi_1\rangle & \langle\psi_2|H|\psi_2\rangle \end{pmatrix} \quad (24)$$

\mathbf{N} is the overlap matrix of the wave functions. Note that if the wave function basis states are already mutually orthonormal, then \mathbf{N} is the identity matrix and the problem reduces to the usual time independent Schrödinger equation.

$$\mathbf{N} = \begin{pmatrix} \langle \psi_1 | \psi_1 \rangle & \langle \psi_1 | \psi_2 \rangle \\ \langle \psi_2 | \psi_1 \rangle & \langle \psi_2 | \psi_2 \rangle \end{pmatrix} \quad (25)$$

ψ is the wave function, a vector in function space spanned by ψ_1 and ψ_2 . That is,

$$\psi = \begin{pmatrix} a \\ b \end{pmatrix} = a\psi_1 + b\psi_2 \quad (26)$$

\mathbf{N} is symmetric and therefore always diagonalizable. We can write \mathbf{N} in diagonalized form with normalized rotation matrices \mathbf{U} . This is preferable to left multiplying by \mathbf{N}^{-1} because this process allows us to obtain orthonormal eigenvectors.

$$\mathbf{N} = \mathbf{U} \mathbf{D} \mathbf{U}^T \quad (27)$$

We seek to reduce our generalized eigenvalue problem to an eigenvalue problem. Noting by the properties of a diagonalized matrix,

$$\sqrt{\mathbf{N}} = \mathbf{U} \sqrt{\mathbf{D}} \mathbf{U}^T \quad (28)$$

Where

$$\sqrt{\mathbf{D}} = \begin{pmatrix} \sqrt{\lambda_1} & 0 \\ 0 & \sqrt{\lambda_2} \end{pmatrix} \quad (29)$$

We left multiply our generalized eigenvalue problem by $\frac{1}{\sqrt{\mathbf{N}}}$ to obtain

$$\frac{1}{\sqrt{\mathbf{N}}} \mathbf{H} \psi = E \sqrt{\mathbf{N}} \psi \quad (30)$$

And by multiplying \mathbf{H} on the right by \mathbf{I}

$$\frac{1}{\sqrt{\mathbf{N}}} \mathbf{H} \frac{1}{\sqrt{\mathbf{N}}} \sqrt{\mathbf{N}} \psi = E \sqrt{\mathbf{N}} \psi \quad (31)$$

Redefining $\frac{1}{\sqrt{\mathbf{N}}} \mathbf{H} \frac{1}{\sqrt{\mathbf{N}}}$ as $\tilde{\mathbf{H}}$ and $\sqrt{\mathbf{N}} \psi$ as $\tilde{\psi}$, we obtain a regular eigenvalue problem.

$$\tilde{\mathbf{H}} \tilde{\psi} = E \tilde{\psi} \quad (32)$$

Calculation of Observables

Having obtained the eigenvector $\tilde{\psi}$, we are interested in computing the expectation value corresponding to some Hermitian

operator Ξ . A natural question is whether one should use ψ or $\tilde{\psi}$ in this calculation. Ξ is calculated identically to the normalization kernel except the observable of interest $\xi(u, v, w)$ is included in the matrix element integral.

$$\Xi_{nm} = \int_0^\infty du \int_0^\infty dv \int_0^\infty dw [\xi(u, v, w) e^{-(u+v+w)} \phi_n \phi_m \tau] \quad (33)$$

Consider the case that $\xi = 1$. We want the expectation value to be identically one.

$$\langle \xi \rangle = 1 = \langle \psi | \Xi | \psi \rangle = \langle \psi | \mathbf{N} | \psi \rangle \quad (34)$$

Since ψ is the eigenvector which is normal under the metric \mathbf{N} it is the eigenvector used to calculate observables in this problem. If we are interested in calculating $\langle u \rangle$, we can write

$$\langle u \rangle = \langle \psi | \mathbf{U} | \psi \rangle \quad (35)$$

Where \mathbf{U} is computed using Eq. 33 letting $\xi = u$. To calculate the expectation value of a triangular coordinate (r_{12} , r_{23} , or r_{13}), we first calculate the expectation values of u , v , and w , and then use the inverse coordinate transformations.

$$\langle r_{12} \rangle = \frac{1}{2a} \langle u \rangle + \frac{1}{2b} \langle v \rangle \quad (36)$$

$$\langle r_{23} \rangle = \frac{1}{2a} \langle u \rangle + \frac{1}{2c} \langle w \rangle \quad (37)$$

$$\langle r_{13} \rangle = \frac{1}{2b} \langle v \rangle + \frac{1}{2c} \langle w \rangle \quad (38)$$

This keeps things simpler—we are only concerned with the perimetric coordinate Jacobian.

Results

Single State Problem

The code from [11] was used to generate the two minimized parameters corresponding to the upper bound of the ground state energy of helium when $\Omega = 0$, i.e. the wave function expansion has only one term, $e^{-1/2 (u+v+w)}$.

$$\delta = 1.6033632 \quad (39)$$

$$\lambda = 2.3176341 \quad (40)$$

The energy given at this level of approximation is -2.889584 which is 0.48% away from -2.90338583, the experimentally determined ground state energy of Helium [18].

Expectation Values

The single state problem is the simplest approximation to solving three body problem. The Hamiltonian, normalization kernel, wave function probability, and observables are all scalars (not matrices, as they are in multi-state problems) which depend on δ and λ . We start by computing the Hamiltonian. Including the constant factors of the Jacobian which [5] ignores), we restate the perimetric coordinate Jacobian τ

$$\tau = \pi^2 \frac{(bu + av)(cu + aw)(cv + bw)}{4a^3b^3c^3} \quad (41)$$

The normalization kernel is computed.

$$N = \int_0^\infty du \int_0^\infty dv \int_0^\infty dw e^{-(u+v+w)} \tau = \frac{\pi^2(2 + 3\lambda + 2\lambda^2)}{2\delta^6\lambda^3} \quad (42)$$

Given these two quantities we can calculate the single state energy from Schrödinger's equation. Keeping in mind that H and N are scalars, we see that

$$H\psi = EN\psi \quad (43)$$

$$\frac{H}{N} = E \quad (44)$$

The Hamiltonian is a function of the parameters δ and λ , so we can minimize it with respect to these parameters to obtain an estimate of the ground state energy of Helium. The sample calculation of the expectation value of u for the single state problem is presented below with its analytic result for arbitrary λ .

$$\langle u \rangle = \frac{1}{N} \int_0^\infty du \int_0^\infty dv \int_0^\infty dw [e^{-(u+v+w)} u \tau] = \frac{3 + 6\lambda + 5\lambda^2}{2 + 3\lambda + 2\lambda^2} \quad (45)$$

In the instance $\lambda = 1$,

$$\langle r_{12} \rangle = \frac{2}{\delta} \quad (46)$$

Note that since the Jacobian is symmetric in u and v

$$\langle u \rangle = \langle v \rangle \quad (47)$$

As expected, $\langle w \rangle$ is different

$$\langle w \rangle = \frac{1}{N} \int_0^\infty du \int_0^\infty dv \int_0^\infty dw [e^{-(u+v+w)} w \tau] = \frac{6 + 6\lambda + 6\lambda^2}{2 + 3\lambda + 2\lambda^2} \quad (48)$$

Calculating the expectation value of r_{12}^2 is slightly less trivial as one needs the expectation values of the cross terms of perimetric coor-

dinates since

$$\langle w \rangle = \frac{1}{N} \int_0^\infty du \int_0^\infty dv \int_0^\infty dw [e^{-(u+v+w)} w \tau] = \frac{6 + 6\lambda + 6\lambda^2}{2 + 3\lambda + 2\lambda^2} \quad (48)$$

And similarly for the other triangular coordinates.

Following the procedure described in section 3.4 (Calculation of Observables), we obtain the following observables for the three body system. All length quantities are measured in units of the Bohr radius.

Observable	Calculated Value	Literature Value [17]
$\langle r_{12} \rangle$	1.385804	1.422070
$\langle r_{23} \rangle$	0.902281	0.929472
$\langle r_{13} \rangle$	0.902281	0.929472
$\langle r_{12}^2 \rangle$	1.943928	2.516439
$\langle r_{23}^2 \rangle$	0.961543	1.193483
$\langle r_{13}^2 \rangle$	0.961543	1.193483

Table 2: Observables of the three body system are calculated using a single state basis function expansion. This expansion is associated with symmetry of the electrons and $\Omega = 0$.

Energy Shift Due to Finite Size of Nucleus

An interesting quantity is the probability density of a single electron being found “inside” the nucleus. This quantity is made interesting by its demonstrated usefulness in calculating the shift in the ground state energy due to the finite size of the nucleus for the two body problem [19]. Letting the first two electrons be particles 1 and 2 and the alpha particle being particle 3, the probability should be calculated when

$$r_{12} = r_{23} \quad (50)$$

and

$$r_{13} = 0 \quad (51)$$

In perimetric coordinates, this corresponds to both v and w being 0, which yields a vanishing Jacobian. If triangular coordinates are used to integrate the wave function, the Jacobian also vanishes since $r_{13} = 0$. The resolution to this issue comes by realizing the problem is spherically symmetric (the general triangle formation of the particles has collapsed to a stick), and thus spherical coordinates can be

used, with r_{12} being the radial coordinate.

$$|\psi(0)|^2 = 4\pi \int_0^\infty dr_{12} [A^2 e^{-2r_{12}} r_{12}^2] \quad (52)$$

For some normalization constant A. The wave function should be normalized such that integration over all space yields a probability of 1. We calculate A from this fact using perimetric coordinates. Note the full Jacobian must be used since the constant multiplicative factors cannot be cancelled with another side of the equation like they were in Eq. 16.

$$1 = \int_0^\infty du \int_0^\infty dv \int_0^\infty dw [A^2 e^{-(u+v+w)} \tau] du dv dw \quad (53)$$

This yields

$$A^2 = \frac{2\delta^6 \lambda^3}{\pi^2(2 + 3\lambda + 2\lambda^2)} \quad (54)$$

and so

$$|\psi(0)|^2 = \frac{2\delta^3 \lambda^3}{\pi(2 + 3\lambda + 2\lambda^2)} \quad (55)$$

Using the numerically calculated parameters δ and λ mentioned at the beginning of this section, we find that

$$|\psi(0)|^2 = 1.65859 \quad (56)$$

While it may appear concerning for this value to be larger than 1, recall that it is a probability density and thus its value depends on the choice of unit volume. Since the length scale of the problem that was set to unity was a_o , the Bohr radius, the above value is implicitly measured in units of $1/a_o^3$. The reason why we are interested in this particular quantity is because, from Eq. 1.13 on page 6 of [19], we see that, for a two body interaction, the change in the ground state energy of the system due to the finite size of the nucleus is given by

$$\Delta E = \frac{4\pi}{5} |\psi(0)|^2 R_{alpha}^2 \quad (57)$$

The radius of the alpha particle R_{alpha} is calculated using the equation

$$R_{alpha} = r_0 N^{\frac{1}{3}} \quad (58)$$

Where $r_o = 1.89036 * 10^{-5}$ is the radius of a single nucleon in units of a_o and N is the number of nucleons (4 for the Helium nucleus). Plugging everything in, we find that

$$\Delta E = 3.75359 * 10^{-9} \quad (59)$$

Given that the ground state energy calculation of the Helium atom without a finite size correction is taken from [5] to be

$$E_{He}^0 = -2.903702 \quad (60)$$

We conclude that the finite size of the alpha particle does make a small but negligible impact on the ground state energy of Helium. The effect is deemed to be negligible since it is 16 at the order of machine error in C++ calculations.

Multi State Problem

Using the code of [11], we determine the minimized parameters corresponding to the upper bound of the ground state energy of helium for a wave function expansion with $\Omega = 2$.

$$\delta = 1.8754959 \quad (61)$$

$$\lambda = 1.8310661 \quad (62)$$

The energy given at this level of approximation is -2.903451 which is 0.0022% away from -2.90338583, the experimentally determined ground state energy of Helium [18].

Normalized eigenvectors are obtained from variational method code of [11]. The eigenvector components c_i are the coefficients of the Laguerre polynomial products which are the basis states of the problem. We performed a resolution study which showed that $\Omega = 2$ yields a less than 1% change in the calculated energy compared to $\Omega = 12$, so we consider the problem using only $\Omega = 2$ and symmetry between the two electrons (since we are only interested in Swave solutions). $\Omega = 2$ and symmetry corresponds to 7 independent basis states. These states were presented in Table 1. The operators corresponding to each observable were computed according to the procedure of Section 3.4. The results are displayed in table 3 in units of the Bohr radius.

Observable	Calculated Value	Literature Value [17]
$\langle r_{12} \rangle$	1.41999	1.422070
$\langle r_{23} \rangle$	0.928635	0.929472
$\langle r_{13} \rangle$	0.928635	0.929472
$\langle r_{12}^2 \rangle$	2.05747	2.516439
$\langle r_{23}^2 \rangle$	1.04134	1.193483
$\langle r_{13}^2 \rangle$	1.04134	1.193483

Table 3: Observables of the three body system are calculated using a 7 term basis function expansion. This expansion is associated with symmetry of the electrons and $\Omega = 2$.

Conclusions

A variational approach to the three body problem was used to calculate observables of the Helium atom at basis expansions of 1 and 7 terms. The anticipated effect of the finite size of the nucleus on the ground state energy is also calculated using the wave function. Additionally, theoretical background used in similar works is given here explicitly: namely, the solution to the generalized eigenvalue problem, the calculation of the Jacobians in perimetric and triangular coordinates, and a discussion of symmetry and degrees of freedom in the three body problem.

While the values calculated in the 7 state expansion appear closer to the literature values tabulated in [17], it would be enlightening to perform a convergence study of the expectation values as a function of the number of basis states to see if there is true convergence to the literature values. Further, a calculation of the expected change in energy due to the finite size of the nucleus for a 7 state expansion would be interesting to compare to the single state approximation.

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REMODELING GENDER IN THE NINETEENTH-CENTURY PARISIAN INTERIOR

Allison Marino

Introduction

In 1863, the publication of Baudelaire's *Le Peintre de la Vie Moderne* defined how nineteenth-century Parisians perceived modernity and gendered expectations of the bourgeoisie class. Baudelaire's flâneur epitomized masculinity as an observer on the boulevard while his characterization of "the woman" as a vehicle "through whom" men could reach creative success colored the perception that women were passive domestic beings unless otherwise invited to participate in the vibrant Parisian exterior by their husband or "patron."¹ Despite its poeticism, contemporary scholars have often considered Baudelaire's collection of essays a factual documentation of nineteenth-century Parisian life. Some, however, have asserted that his strict classification of the Parisian interior/exterior as private/public and female/male, respectively, inaccurately renders a black-and-white understanding of gender in Paris during the 1800s. These scholars further claim that scholarship's reliance on this dichotomy has limited contemporary interpretations of artwork from the period. Temma Balducci is perhaps the biggest challenger of scholarship's reliance on Baudelaire's classification. Balducci highlights the irony between art historians using Baudelaire's polarized classification as a lens through which to view gender in nineteenth-century Paris while
(continued on the following page)

also claiming to be the first wave of “feminist” scholars, simply because they were studying the lives of women.²

In this paper, I examine paintings of women in the interior by well-known nineteenth-century Parisian artists to understand how these artists communicated the true complexity of gender roles and spaces of the period. I argue that artists emphasized their female subjects’ maternal tenderness, educational influence, and leadership of the domestic interior and extended women’s existence to the Parisian exterior to reject Baudelaire’s claim that women were passive byproducts of their spousal relationships.

Edgar Degas’s *The Bellelli Family* (ca. 1858-1867, Paris, Musée d’Orsay, Fig. 1) undermines Baudelaire’s expectations by presenting a dominant female subject juxtaposed with her softened male counterpart. To the left of the composition, Degas paints his Aunt Laure grounded firmly behind her two daughters. The triangular relationship that Degas creates by positioning each of Laure’s arms tenderly toward one of her children dominates nearly two-thirds of the composition, suggesting that the females’ emotional relationship is just as powerful. Laure and her rightmost daughter’s gaze guides the viewer to the right of the image where Laure’s husband, the baron Bellelli, sits. The muted tones of the baron’s clothing in comparison to Laure’s strong, black silhouette seem underwhelming. Further, while Degas paints the women head-on, he provides only a glimpse of the baron’s profile, back of his shoulders, and his left arm. Degas’s incorporation of the baron seems almost an afterthought, yet his depiction of Laure has purpose.³

Degas’s rendering of Laure as head-of-household and his inclusion of the baron as a figure that does not overpower the family portrait contradicts the eighteenth-century perception of the *paterfamilias* that often makes its way into gender studies of early-nineteenth-century Paris. Patricia Mainardi and Amy Freund have both

¹ Charles Baudelaire, *The Painter of Modern Life and Other Essays*, trans. by Jonathan Mayne (London: Phaidon Press Ltd., 1964). Baudelaire primarily defines the flâneur in “III. The Artist, Man of the World, Man of the Crowd, and Child.” The quotes “through whom” references Baudelaire’s repetition of the phrase to describe the role of the modern woman in “X. Woman,” 30.

² Balducci, Introduction to *Gender, Space, and the Gaze in Post-Haussmann Visual Culture: Beyond the Flâneur* (London; New York: Routledge, 2017). For further examples of artists embracing Baudelaire’s dichotomy, see Robert L. Herbert, *Impressionism: Art, Leisure, and Parisian Society* (New Haven: Yale University Press, 1991) and Timothy J. Clark, *The Painting of Modern Life: Paris in the Art of Manet and His Followers* (Princeton: Princeton University Press, Rev. 1999).



Figure 1. Edgar Degas, *The Bellelli Family*, ca. 1858-67. Oil on canvas. 200 cm x 253 cm (79 in x 100 in). Paris, Musée d'Orsay.

discussed the historic role of the *paterfamilias* in domestic life and art in the 1700s.³ The idea of the *paterfamilias* reflects what is typically associated with the “traditional” family dynamic; the husband provides a stable income and has a large social presence while the wife and children are relegated to the home. *The Bellelli Family* underscores the progressive family dynamic that pushed its way into the second-half of the 1800s.

³ I argue that Degas’s portrait signals feminine dominance; however, it is important to note that scholars have different interpretations of this painting. For instance, Silauskas argues that the portrait stands for familial discomfort caused by mourning and an unhappy marriage (Susan Sidlauskas, “Degas and the Sexuality of the Interior” in *Body, Place, and Self in Nineteenth-Century Painting* (New York: Cambridge University Press, 2000), 33.

⁴ Mainardi, “Introduction: To Laugh or to Weep” in *Husbands, Wives, and Lovers* (New Haven; London: Yale University Press, 2003). Amy Freund presents a more artistically-oriented discussion of the male dominance of the family unit in “The Revolution at Home” in *Interior Portraiture*. Freund posits that 18th-century interior family portraiture emphasized masculine control and social standing, a tradition which permeated into artwork of the early-nineteenth-century, primarily of Ingres.

Although existing scholarship does examine—and challenge—male/female roles using portraiture from the period, the discussion is relatively nascent. Balducci notes that although Carol Armstrong examines how nineteenth-century Parisian artists similarly depicted men and women in portraiture, she doesn't discuss the mutual exclusivity of the interior and bourgeois masculinity. Temma Balducci, Heather Belnap Jenson, and Pamela J. Warner come closest to considering the male-female relationship in interior portraiture in their collective publication but stop just short of analyzing this dialogue in paintings created in or after 1800. Moreover, Susan Sidlauskas challenges the male-female convention by considering their gendered roles and interaction in paintings that depict them together, but mainly in consideration to sexuality.⁵ Collectively, scholars have often begun to use the term “flâneuse” when referring to Parisian women out on the boulevard or lounging in parks. The reclaiming of Baudelaire's “flâneur” in a way that similarly suggests autonomy and exterior existence while retaining a sense of femininity has been an important milestone for feminist scholarship. I argue that it is necessary to analyze how painted women in the interior interacted with social expectations guided by literature and government from the period to understand just how interwoven gendered expectations truly were.

Historical and Legal Context for Women

While the perception that women were passive vehicles confined to the domestic interior dominates retrospective scholarship on females from the period, I argue that this perception was less widespread than contemporary readings may perceive. Before 1850, the oscillating rights of women under fast-changing codes and government leadership ultimately provided men with control over the family unit. Patricia Mainardi details the changing gender landscape prior to mid-century mainly in consideration to marriage, adultery, and divorce.⁶ Although she stops just short of 1850, where I begin my analysis, she does acknowledge the emergence of communica-

⁵ Armstrong, *Odd Man Out: Readings of the Work and Reputation of Edgar Degas* (Chicago: University of Chicago Press, 1991). Balducci, Jenson, and Warner. *Interior Portraiture* (2011) Sidlauskas. *Body, Place, and Self* (2000).

⁶ Mainardi, “Introduction” in *Husbands, Wives, and Lovers* (2003).

tion between artists and society after the 1789 revolution wherein artists engaged with the legal landscape by “upholding, critiquing, or rejecting” social transformations in their art work.⁷ Furthermore, Mainardi proposes that examining post-revolutionary works in light of social context enables viewers to “see more clearly their ideological thrust and... uncover, like archeologists, hitherto unknown strata of the *mentalité* of the epoch.”⁸ This is what I propose to do.

Values upheld by the Second French Empire under Napoleon III (1852-1870) were progressive in comparison to the pre-revolutionary family structure of the dominant husband and obedient wife. The revolution brought with it an irrational fear of the new generation of sons uprising against the government. Thus, “women, and particularly young girls, came to signify the regenerative possibilities of post-Revolutionary culture” in art work.⁹ Artists reflected these possibilities by incorporating more female subjects into their paintings produced after 1789. The government acknowledged these possibilities legally by instituting laws that increased female autonomy, such as enabling women to divorce their husbands in instances of his unfaithfulness and granting daughters—as opposed to just sons—the right to inheritance following their fathers’ death. However, society remained reliant upon relatively conservative values. It was not until the Third Republic (1870-1940) that leaders attempted to progressively counteract the near-authoritarianism of the Second Empire. During this period, society’s efforts to increase female autonomy ignited, an event contemporaneously referred to as “The Woman Question.”¹⁰ Incited by the publication of André Léo’s collaborative manifesto in 1868, women who were determined to achieve equality in law, marriage, work, and sociality directed the socially progressive landscape of late-nineteenth-century Paris.¹¹

⁷Mainardi, “Introduction,” 2.

⁸Mainardi, “Introduction,” 2.

⁹Jenson, “Picturing Paternity,” 35.

¹⁰Karen Offen, “General Introduction: What do Women Want?” in *Debating the Woman Question in the French Third Republic, 1870-1920* (Cambridge, UK: Cambridge University Press, 2018).

¹¹Offen, “Taking Stock: The Woman Question on the Eve of the Third Republic” in *The Woman Question in France, 1400-1870* (Cambridge, UK: Cambridge University Press, 2017), 240; “La Femme dans la démocratie,” written by André Léo and eighteen other women, was published in 1869. Offen considers this publication to be revolutionary to the start of the revolution in “Taking Stock.”

I argue that artists working in the second-half of the nineteenth-century reflected social expectations previously established under the Civil Code/Second Empire by containing many of their female subjects in interior spaces. However, they incorporated the socially progressive mindset of the late-1800s into their work by painting autonomous females as domestic leaders. One way that women achieved leadership status with the viewer was with direct gaze. Although Baudelaire normalized “the gaze” as a characteristic of the male flâneur, and consequently of masculinity, progressive artists such as Manet and Degas challenged this association by suggesting female power through looking.¹²

Art and Female Autonomy

Artists further emphasized female domestic leadership by depicting mothers reading to or teaching their children. Mothers educating their children became a popular compositional motif in Parisian painting after 1850. One example is Renoir’s *The Writing Lesson* (c. 1895, Private Collection, Fig. 2). The painting depicts a woman, likely middle-class, who is patiently teaching her young daughter to write. Renoir’s Impressionist style, including his soft brushstrokes and warm color palette, further emphasizes the mother’s tenderness and connection to her daughter in the fleeting moment he captures. At first glance, the painting may appear to be nothing more than a mother in the interior taking care of her daughter. Some may even read the image as a testimony to the hardship that women faced in being assigned domestic duties.

I argue that this painting does the opposite. Nineteenth-century etiquette manuals underscored the significance of “maternal education,” and the “mother-teacher” became prominently upheld as an empowered female character by supporters of gender equality after 1870.¹³ Louis Aimé-Martin’s *De l’éducation des mères de famille*

¹² Balducci, “Gazing Women” in *Gender Space and the Gaze* (2017), 4. I discussed an example of Degas using the female gaze to heighten women’s autonomy in regard to *The Bellelli Family*. Manet’s use of the female gaze to increase female autonomy was slightly more complex and sexually-charged. In Manet’s *Olympia*, for instance, he challenges the passiveness of Renaissance female nudes (e.g. Titian’s *Venus of Urbino*) by rendering Olympia as a powerful figure who is confident in her nudity. Olympia’s direct gaze with the viewer gives her control of her body and challenged the previous notion that nude women existed solely for the male gaze.

¹³ James McMillan, “Angels of the hearth?” in *France and Women, 1789-1914* (London: Routledge, 2002), 41.



Figure 2. Pierre-Auguste Renoir, *The Writing Lesson*, 1895. Oil on canvas. 41.28 cm x 32.07 cm. Private Collection.

ou de la civilisation du genre humain par les femmes was the most impactful of these manuals. Published in Paris in 1834, Aimé-Martin argued that because women were the dominant influencers of morality, schooling, and social behavior, they not only held vast power because they were raising the next generation, but their power dictated men's behavior in the exterior.¹⁴ Though it may appear inherently confining, I argue that motherhood gave women independence and respect. Women, in being the primary influencers of their child(ren)'s social and moral principles, maintained ultimate social leadership in nineteenth-century Paris. Moreover, I argue that artists acknowledged women's authority by making them active leaders in interior settings.

¹⁴ McMillan, "Angels of the hearth?," 41-42.

I further posit that artists emphasized maternal tenderness to create empowered female subjects. By depicting women who were patiently and lovingly engaged in the lives of their children, artists likely elicited emotional responses from viewers who were able to place themselves in the position of the child(ren) being taught, thus extending women's power through viewer-associations. Instead of villainizing their female subjects for having power unobtainable by men, artists filled interior scenes with respectable women whose children found their leadership fulfilling.

It is worth noting that in a society obsessed with maintaining boundaries between the bourgeoisie and anything below, artists ensured that maternal tenderness persisted across representations of different classes. Renoir, for instance, also painted *Washerwoman and Child* [*La Blanchisseuse et son enfant*] (1886, Philadelphia, Barnes Foundation, Fig. 3) and *Camille Monet and Her Son Jean in the Garden at Argenteuil* (1874, Washington, D.C., National Gallery of Art, Fig. 4). In the former, Renoir portrays his wife, Aline, as a low-class working woman gazing lovingly at their first child. As with many nineteenth-century painters, Renoir embraced “the washerwoman” motif throughout his career.¹⁵ Renoir conceptualized his working women differently, however, because he did not sexualize his figures. Eunice Lipton, for instance, argues that Degas's paintings of laundresses and ironers were sexual because of his intrinsic anxieties about sex and thus his working women's character were demoralized.¹⁶ I argue that Renoir did not compromise the virtue of his washerwomen because he did not share similar sexual anxieties and he depicted his own wife and son in this role. Therefore, it is appropriate to read this image as an indicator of maternal tenderness rather than overt sexualization or degradation of female character. In Renoir's *Camille Monet and Her Son Jean in the Garden at Argenteuil*, middle-class Camille Monet is depicted lounging in the artist-family's private garden while her son comfortably rests his head on her lap. I

¹⁵ Renoir worked closely with sculptor Richard Guino to create a series of bronze sculptures. Their collaboration culminated in several largescale bronzes—*The Washerwoman* (c. 1917–18; London, UK., The Tate); *Washerwoman* (c. 1916; New York City, The Metropolitan Museum of Art); *The Large Washerwoman* (c. 1917; Philadelphia, PA., The Philadelphia Museum of Art)—and several sketch studies and smaller-scale bronzes.

¹⁶ Lipton argues the sexuality present in Daumier and Degas's art of laundresses and ironers in “The Laundress in Late Nineteenth-Century French Culture” in *Modern Art and Modernism*, ed. by Frascina and Harrison (New York: Harper & Row, 1980).



Figure 3. Pierre-Auguste Renoir, *Washerwoman and Child* [*La Blanchisseuse et son enfant*], 1886. Oil on canvas. 81.3 cm x 65 cm (32 in x 25 9/16 in). Philadelphia, The Barnes Foundation.



Figure 4. Pierre-Auguste Renoir, *Camille Monet and Her Son Jean in the Garden at Argenteuil*, 1874. Oil on canvas. 50.4 cm x 68 cm. Washington, D.C., The National Gallery of Art.

argue that the transmission of maternal tenderness across class boundaries underscores its artistic success as a motif for both female power and viewer pleasure.

Nineteenth-century Parisian painters further complicated the strict classification of women to the interior and men to the exterior by using windows and balconies to extend women's interior presence out to the boulevard. In Berthe Morisot's *The Artist's Sister at a Window* (c. 1869, Washington D.C., National Gallery of Art, Fig. 5), the artist depicts her bourgeoisie sister examining what appears to be a painted fan in front of an open window. While Morisot's sister is the focal point of the image, the painted details of the exposed Parisian exterior draw the viewer outside. Scholarship on the role of windows as extensions of the interior is minimal, though Balducci sparked discourse on the topic by using instances of windows and balconies in nineteenth-century French painting as vehicles to challenge the interior/exterior private/public dichotomy.¹⁷

The setting of Morisot's painting likely mirrors a typical Haussmann apartment. As urbanization drove up the costs of building in Paris, architects began to replace interior garden spaces with long windows, such as the one Morisot depicts, to provide bourgeoisie residents with views of the city from their private interior. Public living spaces were often oriented to face the street for the intended observer's pleasure. As construction under Haussmannization made spending time on the boulevard both visually unpleasant and bad for one's health, windows offered gazers the chance to participate in the vibrant exterior from the safety and comfort of their own homes. While scholars such as Peter Stallybrass, Allon White, and Sharon Marcus argue that the primary purpose of windows was to protect the bourgeoisie from urban society, thus strengthening the boundaries between private and public, I argue that windows gave women a perceived masculine power: the power to gaze.²¹ Paintings, such as

¹⁷ Balducci, "Windows and Balconies" in *Gender, Space, and the Gaze* (2017).

¹⁸ Balducci, "Windows and Balconies," 115.

¹⁹ Balducci, "Windows and Balconies," 116.

²⁰ Marni Kessler discusses the negative effects of Haussmannization on air quality and public health in "Dusting the Surface: the Veil, the Bourgeoise, and the City Grid" in *The Invisible Flâneuse?* (Manchester: Manchester University Press, 2006).

²¹ Peter Stallybrass and Allon White, *The Politics and Poetics of Transgression* (Ithaca, NY: Cornell University Press, 1986). Sharon Marcus uses Zola's *Pot-Bouille* (1882) to argue that strict separation of private and public in Parisian life in *Apartment Stories: City and Home in Nineteenth-Century Paris and London* (Berkeley, CA: University of California Press, 1999).



Figure 5. Berthe Morisot, *The Artist's Sister at a Window*, 1869. Oil on canvas. Overall: 54.8 cm x 46.3 cm (21 9/16 in x 18 1/4 in), Framed: 74.93 cm x 67.31 cm x 10.8 cm (29 1/2 in x 26 1/2 in x 4 1/4 in). Washington, D.C., The National Gallery of Art.

Morisot's, that depict women next to a window or balcony extend their sense of belonging to the Parisian exterior as an observer, the very role that Baudelaire characterized as strictly masculine in his essays.

Moreover, the fact that Parisian painters commonly chose to use this subject matter to inspire their compositions validates that women gazing from their homes occurred often. Gustave Caillebotte's *Interior, Woman at the Window* (c. 1880, Private Collection, Fig. 6) depicts a wife gazing out of her apartment window while her husband sits, consumed by a newspaper, in the right foreground. Caillebotte's use of a dark color palette and his emotional disassociation between the viewer and the gazing woman communicates a sense of longing. Caillebotte de-personalizes the woman by hiding her face and incorporates what appears to be another gazing woman in the apartment across from our subject's to prompt. I argue that Caillebotte uses these techniques to generalize the confinement that these two women

feel to the entire Parisian female population.

In Berthe Morisot's *Eugène Manet on the Isle of Wight* [*Eugène Manet à L'île de Wight*] (1875, Paris, Marmottan Monet Museum, Fig. 7), the artist maintains the window motif but completely reverses her presentation of gender. In the composition, Morisot's husband gazes longingly out of a window in their home at a mother and her young daughter conversing outside. Morisot challenges the male/female public/private dichotomy directly. The painting communicates a reversal of the female longing seen in Caillebotte's composition and Morisot encourages viewers to contemplate a world with reversed gender expectations in a work that is colorful, engaging, and even uncomfortable to a nineteenth-century audience.

Literary sources from the period further embrace the character of "the gazing woman." In Balducci's reading of Emille Zola's *Pot-Bouille* (1882), for instance, she argues that what outwardly appears to be Zola's attempt to separate the interior from the exterior and private from public life is actually his metaphorical break down of the divisions of these spaces. By arguing that the perceived "safe" and "moral" interior actually mirrored the scandalous Parisian exterior, Zola challenges the nineteenth-century perception of the interior as a moral sanction.²² Most of the novel takes place inside a bourgeois apartment building, so Zola uses windows through which his characters observe the outside world to draw parallels between the immorality of both the interior and exterior. In Zola's sequel, *Au Bonheur des Dames* (1883), he incorporates well-lit windows as invitations for outdoor Parisians to look inside a popular department store, further using windows to slash boundaries between interior and exterior spaces. In *Le Ventre de Paris* (1874), Zola's antagonist Mme. Saget stays up-to-date on gossip by observing Parisians on the boulevard from her window.²³

It is important to note that while these literary sources popularize the window as an extension of female belonging, they also demoralize women's character. Often, the women looking at these boundaries are doing so to incite drama or for the sole purpose of

²²Balducci, "Windows and Balconies," 118; Emille Zola, *Pot-Bouille* (Charpentier: serial 1882, book form 1883).

²³Zola, *Au Bonheur des Dames* [The Ladies' Paradise], (Charpentier: 1883); Zola, *Le Ventre de Paris* [The Belly of Paradise], (1873).



Figure 6. Gustave Caillebotte, *Interior, Woman at the Window*, 1880. Oil on canvas. Private Collection.



Figure 7. Berthe Morisot, *Eugène Manet on the Isle of Wight* [*Eugène Manet à l'Île de Wight*], 1875. Oil on canvas. 38.1 cm x 46 cm (15 in x 18.1 in). Paris, Musée Marmottan Monet.

gathering the latest gossip. Nonetheless, period literature embraces the power and acknowledges the existence of the female gaze. Moreover, it situates women as active participants in Parisian exterior life even if their participation is problematic.

Similar to how windows functioned as a motif for exterior existence, balconies further challenged women's confinement to the interior by allowing them to physically be outside. Mary Cassatt's *Young Girl at a Window (Susan on a Balcony Holding a Dog)* (ca. 1883-84, Washington, D.C., National Gallery of Art, Fig. 8) depicts a young woman gazing down at the Parisian streets holding her dog. In her reading of this painting, Balducci also notes that Cassatt's rendering of the woman as unoccupied with a "feminine" activity further removes her from constricting femininity.²⁴

Private gardens also served as artistic extensions of women to the outdoors. Jane R. Becker analyzes the transformative power of private gardens in creating the female flâneuse in her study of the life and work of Marie Bracquemond.²⁵ Becker argues that private gardens were a sort of "stepping stone" between sole female existence in the interior and the full-blown exterior experience of the flâneuse. Depicting female subjects in their private gardens, as Renoir did with *Camille Monet and Her Son Jean in the Garden at Argenteuil*, challenged the beliefs that women could only relax in the home and had to be accompanied by a man to stroll in parks or public gardens and remain "respectable."

Finally, I argue that artists used newspapers to challenge the female-interior-private association. Kathryn Brown unpacks the progressive weight that newspapers carried during and after 1870 in Paris largely in relation to Mary Cassatt's *Lydia Reading the Morning Paper* (ca. 1878-79, Omaha, NE, Joslyn Art Museum, Fig. 9).²⁶ Morisot depicts her sister, Lydia, reading a daily French newspaper. Lydia's slouched posture indicates a private moment that the viewer is impeding on which I argue only adds to the narrative's truthfulness. Lydia is unaware that she is being observed, thus she exists

²⁴ Balducci, "Windows and Balconies," 132.

²⁵ Jane R. Becker, "Marie Bracquemond, Impressionist Innovator: Escaping the Fury" in *Women Artists in Paris, 1850-1900* (New Haven: Yale University Press in association with the American Federation of Arts, 2017), 64-65. Exhibition Catalog.

²⁶ Kathryn Brown, "Unfolding the Domestic Interior: Women, Newspapers and the Nineteenth-Century City" in *Reconfiguring the Feminine in the Urban Environment*, ed. Siobhán McIlvanney and Gillian Ní Cheallaigh (Cardiff: University of Wales Press, 2019).



Figure 8. Mary Cassatt, *Young Girl at a Window (Susan on a Balcony Holding a Dog)*, c. 1883-84. Oil on canvas. Overall: 100.3 cm x 64.7 cm (39 1/2 in x 25 1/2 in), Framed: 133.99 cm x 96.52 cm x 12.7 cm (52 3/4 in x 38 in x 5 in). Washington, D.C., The National Gallery of Art.



Figure 9. Mary Cassatt, *Lydia Reading the Morning Paper*, c. 1878-79. Oil on canvas. Dimensions Unknown. Omaha, Joslyn Art Museum.

without the obligation to behave properly. Morisot's removal of setting, space, and time with soft brushstrokes and arbitrary, solid masses of color underscore Lydia's immersion in the words she is reading. Brown posits that women reading newspapers reduces the boundaries between public and private because they are actively participating in urban news. She also argues that women's involvement with daily external affairs negates the passive, gazing character of the *flâneuse* and empowers women in a new dimension as critics of politics, culture, and society. Moreover, Brown writes that newspaper editors and marketers began to direct many of their advertisements towards female viewers.²⁷ This suggests that society was not only aware that women were reading and forming opinions about current events but was also validating their commercial power. Near the end of the century, society acknowledged increased female participation.

Lydia is visually comparable to the cornered male figure reading the newspaper in Caillebotte's composition; however, the act communicates a different meaning in each one. In Caillebotte's image, his portrayal of the husband suggests detachment. The fact that he is reading while his wife stares longingly out of their private window associates the act less with leisure and more with boredom, both with his wife and the world around him. As the man is dressed in common *flâneur* attire, it is appropriate to assume he behaves as one. Perhaps the man is bored of his monotonous existence as observer on the boulevard and retreated home to escape the exterior. Perhaps reading a newspaper is his way of keeping abreast of politics, culture, and society from the privacy of the interior.

Although the newspaper communicates Lydia's participation in these same three realms, Morisot gives the act positive connotations. Lydia reading signals the rise of an entire gender's involvement with Parisian boulevard life. While Caillebotte's male figure represents a gender unfulfilled by exterior existence, Morisot's female subject symbolizes the ignition of women's belonging in late-nineteenth-century painting and in society. While there is more to be analyzed about how artists represented both women and men in painting from the period and how these representations challenged the interior/exterior dichotomy between them, it is clear that gendered

²⁷ Brown, "Unfolding the Domestic Interior," 56.

expectations were more complex than Baudelaire described. Artists have always maintained discourse with the world around them in their work. In the case of the second half of the nineteenth-century, analyzing this discourse reveals that artists were often progressive in their depictions of the interior by challenging their perceived sole domestic purpose and heightening women's individual autonomy and social leadership.

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FUTURE PROJECTIONS FOR THE EFFECTS OF CLIMATE CHANGE ON TERRORIST NETWORKS IN THE MIDDLE EAST

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Abstract

Across the Middle East, terrorist organizations such as the self-styled Islamic State militant group have shown their ability to exploit environmental conditions in pursuit of their objectives. Through targeting vulnerable populations affected by the early stages of climate change, the Islamic State has been able to supplant government authority in certain regions of Iraq and Syria, including the major cities of Mosul and Raqqa. Exploiting these governments' inability to assist those affected by environmental disasters, to recruit new members and sympathizers, the Islamic State has proven that terrorist groups will have the resources to thrive throughout the 21st century, as changing climate conditions create suitable opportunities for terrorist groups to outcompete their rivals. In the event that the Intergovernmental Panel on Climate Change (IPCC)-projected climate change does occur, we can expect that much of the Middle East will become even more fertile for the cultivation of terrorist and insurgency groups. As a warming atmosphere forces millions into poverty and water continues to grow more scarce, terrorist organizations will have the capacity to exploit the vulnerabilities of the destitute and disenfranchised, potentially growing more and more powerful until the power of these groups rivals and surpasses that of local governments.

It has been nearly a decade since the northern Iraqi village of Shirqat first began to experience the severe droughts which it still suffers from to this day (Schwartzstein 2017). As an agricultural village, these droughts brought the village far beyond the limits of relative deprivation and to the brink of absolute deprivation. Meanwhile, the fragile Iraqi government was in no position to offer aid, as the country still struggled to recover from the American-led invasion in 2003 and the subsequent occupation of the country. The government's inability to act left a vacuum in the region, drawing the attention of extremists from the self-styled Islamic State militant group, better known in the West as the Islamic State of Iraq and Syria (ISIS). "Join us, and you'll never have to worry about feeding your family," the Islamic State recruiters would preach to the village's residents (Schwartzstein 2017). In the years following, droughts, floods, and other natural disasters were accompanied by visits from recruiters from the Islamic State, who would bring gifts of food and money to the villagers. Not much time would pass before a number of villagers would begin to trade their farming tools for assault rifles and run off to fight alongside jihadists in Iraq, Syria, and elsewhere in the Middle East (Schwartzstein 2017).

This experience has not been isolated to the village of Shirqat. In countries such as Iraq, Syria, Libya, and Somalia, terrorist groups such as the Islamic State have been able to entice vulnerable populations in unstable states with promises of safety and wealth in order to recruit members and establish strong foundations. In many of these states, harsh climate conditions—including droughts, floods and heat waves, among others—have played a significant role in developing this instability. Across the Middle East, changing environmental conditions, such as those driving drought conditions in Shirqat, have only added fuel to the growing fire started by terrorist groups such as the Islamic State. Meanwhile, the impending threat of climate change holds the potential to further exacerbate these worsening conditions. This would ultimately open new opportunities for terrorist groups to find and manipulate vulnerabilities in the social order to further their objectives (Schwartzstein 2017; Sly 2016).

At the sociological level, terrorists are not born, but are created as a response to the environment they find themselves in (Vertigans 2011). Once we accept this fact, it allows us to analyze the particular

environments—including climate conditions—which breed and perpetuate terrorist ideologies. More importantly, though, is that through this understanding, we come to realize that terrorism is a rational choice. This choice is driven not by mental illness, but by the belief that there is some injustice in the world and that violence is the most effective means to correct this injustice (Forest 2006). Simply put, terrorism is not the work of fanatics murdering without reason; rather, terrorism is, in the borrowed words of Carl von Clausewitz, “the continuation of political intercourse, with the addition of other means” (Clausewitz 1832).

However, in regard to the aforementioned points, it is also necessary to clarify that while terrorism is a choice, this choice does not come easily. Rather, the decision to join a terrorist organization often results from a myriad of structural and environmental forces which fuel perceptions of victimization and oppression at the hands of those with power and authority (Forest 2006). Ultimately, the product of this is, as described by psychologist John Mack, a “reservoir of misery, hurt, helplessness, and rage from which the foot soldiers of foot soldiers of terrorism can be recruited” (Mack 2003). Across the Middle East, the inability or unwillingness of those in power to alleviate the suffering of their people has already produced generations of individuals affected by this reservoir who are susceptible to terrorist recruitment. As climate change continues to threaten the world, its consequences have the potential to exacerbate the conditions which give rise to and empower terrorist networks, especially in regions such as the Middle East, where these networks already hold significant grip (Doherty 2017).

Understanding the root causes for terrorists’ motivations requires us to analyze the dynamics of terrorism on three levels: micro, meso, and macro (della Porta 2004). The microdynamic approach typically centers on an individuals’ psychological state and personal characteristics (Kinloch 2005). However, the dominant research thus far agrees that terrorists are, generally, psychologically normal, at least prior to their radicalization (de Zulueta 2006). A 1973 study by sociology Irving Horowitz created a profile for terrorists which still holds ground today. Specifically, the study suggested that the majority of terrorists are male, young, middle class, economically marginalized, self-destructive, willing to self-sacrifice, and lack a

well-defined ideological persuasion (Horowitz 1973). Despite the study being decades old—older than the Islamic State—these attributes have been well observed among members of the Islamic State (Long 2015; Dearden 2016; Gómez et al. 2017). However, more important than an individual's personal characteristics are the broader characteristics of a group or society which may provide adequate conditions for terrorism, leaving us with the mesodynamic and macrodynamic explanations for terrorism.

At the mesodynamic level, group characteristics such as shared ideology, strategies, and organizational resources are of most concern (Dobratz et al. 2019). Among the more important contributions of the mesodynamic approach, as it applies to this paper, is the approach's focus on strain theory. Strain theory argues that social deviance results from a break between cultural goals and culturally accepted means to achieve those goals (Dobratz 2019; Merton 1968). The disconnect between these two is known as strain and may result in a rejection of social norms and the socially accepted means of achieving cultural goals. Looking back to the village of Shirqat, the inhabitants of the village accepted the cultural goal of survival; however, when faced with drought, the only means of reaching this goal were to either relocate to an area with food and water or accept gifts from the Islamic State. The latter was obviously the preferable option; as such, the villagers of Shirqat did indeed accomplish the culturally accepted goal, but only through socially unacceptable means. Though not a perfect example, it does display that the choice to align with a terrorist organization is not purely ideological. Often times, the decision is made in order to reach goals that would be otherwise impossible.

Terrorism, at the macrodynamic level, is the result of broader social, economic, and political forces acting upon individuals (Dobratz et al. 2019). Often times, it is the combination of grievances with these forces and the inability to peacefully resolve these grievances which drives individuals to sympathize with and potentially join terrorist organizations (della Porta 2004). While these grievances may center around any perceived injustice, the most common involve: a lack of political power, severe economic stress, rapid social change, perceived threats to national interests, and political conflict (Taylor and Louis 2003; Dobratz et al. 2019). In addition, relative deprivation and oppression within society both serve as root structural causes for

terrorism (Marsella 2003; Matusitz 2013). Furthermore, dispossession, defined as “perceptions on the part of the group that is systematically excluded, discriminated against, or disadvantaged with respect to some meaningful aspect of social economic, and political life to which it feels entitled” (Smelser 2007: 16) serves as a key influence on terrorism.

These perceptions of exclusion and deprivation have been largely fueled by globalization, a process which will certainly continue well into the foreseeable future. Through widespread communication, the Internet, and tourism, globalization has made it possible for individuals in developing countries to compare their own standard of living to those from wealthier countries. This has inadvertently fostered strong feelings of hatred in developing countries for those guilty of “fattening at the expense of the plundered majority of earth inhabitants” (Galkin 2006; Matusitz 2013). These perceptions of grave inequality are not unfounded, with wealthy nations such as the United States benefiting from the consumption of cheap resources and labor in less wealthy “periphery” countries. The effects of this inequality have already been observed in the Middle East, with resentment towards the West for perceived exploitation leading many working-class Arabs to embrace militant Islam (Martin 2007; Matusitz 2013; Toth 2003; Dobratz et al. 2019). It is also important to note that we need not question whether climate change will exacerbate this inequality, as numerous studies (Diffenbaugh and Burke 2019; Burke 2015) have established that this has already taken place over the last several decades (Worland 2019). Therefore, it is apparent that, at the macrodynamic level, terrorism is already, ostensibly, being fueled by climate change. It is this assumption that will guide the rest of this paper and lend credence to the argument that climate change and terrorism are inexorably linked together.

Building off of these assumptions, we can look at the specific environmental conditions in the Middle East which have the capacity to create terrorist militants and fuel the growth of terrorist organizations. Thus far, there has been widespread debate on how climate change will impact climate conditions in the Middle East; however, one study (Lelieveld 2016) predicts that by the middle of the century, summer temperatures across the Middle East will reach approximately 46°C (114.8°C). These changes would leave many heavily populated areas of the Middle East essentially uninhabitable, leaving the

fate of nearly 400 million people in dire straits. For these climate refugees, the only option for survival would be to flee to unaffected lands nearby. This mass migration of individuals this would lead to extensive resource strain and political dissatisfaction, thereby weakening governments in the region and cultivating environments where terrorism can thrive. Due to the direct impact that these climate change-induced temperature increases are likely to have on the region, surface temperature will be the primary focus for this paper. However, considerations must also be given towards precipitation, evaporation, and humidity, as these factors are also crucial elements in assessing environmental conditions throughout the Middle East. The potential for devastation that changes in precipitation, evaporation, and humidity have in the Middle East cannot be overstated. In the past, droughts and flooding have already been exploited by the Islamic state in pursuit of their objectives and recruit new members from the pool individuals affected by these environmental phenomena (Gerretsen 2019). As a result, precipitation, evaporation, and humidity have also been looked at in how they will likely influence changing climate conditions in the Middle East.

The aim of this paper is to analyze how the Islamic State militant group has utilized the physical climate conditions of the Middle East to pursue their objectives as a terrorist organization, as well as the potential impact that climate change will have on the future of terrorism in the Middle East. More specifically, the purpose of this study is to determine the impact that changing climate conditions will have on the development of an environment where terrorism can thrive across the Middle East. Furthermore, I will analyze how changing environmental conditions may affect the governments in these regions, and whether these impacts will aid or hinder in these governments' ability to suppress the growth of terrorist networks.

Methodology

Drawing on information gathered using the Global Climate Model (GCM) developed by the Goddard Institute for Space Studies at the National Aeronautics and Space Administration (NASA), this study analyzed environmental changes that are likely to occur in the 21st century throughout the Middle East. More specifically, I analyzed and compared changes that would be likely to occur under two conditions: 1) Conditions under the Intergovernmental Panel on Climate

Change's (IPPC) A1F1 scenario and 2) Conditions under CO₂ levels in 2019. The former of these two scenarios is traditionally known as the "business-as-usual" scenario, wherein greenhouse gas emissions continue to be emitted with little to no reduction efforts (Riahi et al. 2011). The latter of these two scenarios has been used as a baseline measurement to compare how conditions in the future will differ from conditions in the present.

This data was then compared with the impacts that climate conditions and weather events have had on the growth or decline of terrorist organizations in the past to predict how climate change is likely to influence terrorism in the future. Specifically, this paper is centered around past strategies used by the Islamic State and al-Qaeda as examples of how terrorist groups exploit environmental conditions to expand and recruit new members.

Defining "Terrorism"

The definition of terrorism has long been and continues to be a highly contested term among academics, politicians, journalists and any other parties concerned with political violence. However, for the purposes of this paper, "terrorism" has been defined broadly as a political tactic wherein a group exploits violence and the fear of violence to intimidate a larger audience than those initially affected by the immediate actions of said group. This definition opens the door for terrorism to be perpetrated by both state and non-state actors. Regardless, due to the focus of this paper centering around the Islamic State, the term "terrorism" will apply exclusively to terrorism as a tactic used by sub-national groups and not to political violence by actors within a state apparatus.

The Global Climate Model

Accessed using the EzGCM software developed by Columbia University, the Global Climate Model was used in order to draw predictions for changes in future climate conditions across the Middle East, including: 1) Surface Temperature and 2) Precipitation, Evaporation, and Humidity.

The data for each of these conditions was generated for two scenarios, which were then compared in order to determine a difference. The first scenario measured was the Intergovernmental Panel on Climate Change's (IPCC) A1F1 or "business-as-usual" scenario. The second scenario plotted conditions under CO₂ levels in the year 2019.

Surface Temperature

In the desert-speckled regions of the Middle East, surface temperature remains among the most difficult elements to life in the hostile environment. However, the exceptionally high temperatures found in this arid region are only likely to increase alongside climate change.

Using the Global Climate Model, I analyzed visualizations concerning temperature change in the Middle East under the “business-as-usual” scenario and the baseline scenario. Specifically, I measured the projected surface temperature increase broadly at the annual scale, as well as more in-depth by looking at temperature change in the Spring (March, April, May), Summer (June, July, August), Autumn (September, October, November) and Winter (December, January, February) seasons.

Precipitation, Evaporation, and Humidity

For the purposes of this article, I have primarily relied on already-established projections from the IPCC to determine future changes to precipitation, evaporation, and humidity in the Middle East. Additionally, I have also used the Global Climate Model to corroborate the results for precipitation and evaporation, which measures the data in terms of millimeters per day (mm/day). Both of these resources were used to provide insight into how significant any changes in precipitation, evaporation, and humidity will be in the Middle East throughout the century.

Defining Wet Bulb Temperature

While data regarding surface temperature and humidity are, on their own merits, significant when considering the influence of climate change in the Middle East, a more accurate representation of how climate change conditions will influence daily life would be to look at how the wet-bulb temperature of the region will change. In simplest terms, wet-bulb temperature is the lowest temperature that an individual’s body can reach under particular conditions through sweat evaporation, and can be calculated with the Stull Formula:

$$T_w = T \tan[0.151977(RH\% + 8.313659)^{1/2}] + \tan(T + RH\%) - \tan(RH\% - 1.676331) + 0.00391838(RH\%)^{3/2} \\ \tan(0.023101RH\%) - 4.686035,$$

Where: T_w is the wet-bulb temperature, T is the dry-air temperature (or simply, air surface temperature) and RH is the relative humidity (Stull 2011).

Theoretically, in dry-bulb temperature conditions, people are capable of survival in temperatures in excess of 45°C (113°F), with temperatures in the Middle East easily reaching up to 52.1°C (125.8°F) without significant loss of life. However, using wet-bulb temperature measurements, we can estimate a limit to human adaptability in regard to heat. Currently, research points to the threshold for human survivability to be 35°C (95°F). Under these conditions, exposure to outside heat is almost certain to be fatal, even for the healthiest of humans (Sherwood and Huber 2010). This risk is even greater for children, the elderly, and other vulnerable individuals, such as the impoverished.

Using data derived from the Global Climate Model and findings from the IPCC, the Stull Formula was used to calculate potential wet-bulb temperature ranges across the Middle East in the future.

Results

Projections from both the Global Climate Model and IPCC agree that the future of the Middle East will be shaped by a changing climate and its inhabitants attempts to adapt to it. Under the “business-as-usual scenario,” surface temperatures will increase by up to and 7°C (44.6°F), bringing significantly warmer temperatures to a region which already known for being arid. Furthermore, it is projected that humidity will not shift significantly during this same period, which would lead to an overall increase in wet-bulb temperature. Should “business-as-usual” projections come to pass, it is increasingly likely that much of the Middle East—including a number of its major population centers—will become uninhabitable by the end of the 21st century.

These changes will place a heavy strain on the governments and populations of the region, especially in regard to resource scarcity and inhabitable territory. Therefore, should climate change continue along a “business-as-usual” scenario path, it is likely that terrorist organizations in the Middle East will exploit radically deteriorating climate conditions in order to occupy economic and social vacuums in Middle Eastern societies, thereby becoming dominant actors in the region. Many of the observed results reflect those already known to affect economic conditions (Diffenbaugh and Burke 2019; Burke 2015) and political stability in the Middle East (Garretsen 2019), thereby leading to the conclusion that failure to mitigate future pro-

jections will lead to the same results.

Surface Temperature

Current projections from the Global Climate Model under the “business-as-usual scenario” predict that temperatures in the Middle East will increase drastically. By 2100, temperatures in the Middle East can be expected to rise by between 1°C (33.8°F) and 7°C (44.6°F) across most of the region. In the Winter months of December, January, and February, temperatures in the Middle East are likely to rise by at least 5°C in most countries. However, more concerning is the drastic increases which are projected to take effect during the Summer months of June, July, and August, where already-high temperatures may rise by between 3°C (37.4°F) and 7°C (44.6°F).

With average summer temperatures ranging from 37°C (98.6°F) in Damascus to 47°C (116.1°F) in Kuwait City, the Middle East already experiences extreme temperatures from June to August. In addition, heat waves are a common occurrence across the Middle East, with these heat waves bringing with them temperatures as high as 49.3°C (120.7°F) in Mosul and 54°C (129.2°F) in Ahvaz. As heat waves in the Middle East are only predicted to increase in frequency and severity (Perkins et al. 2012), temperature alone will have a severe impact on the lives of people in the Middle East as the 21st century progresses.

Precipitation, Evaporation, and Humidity

As it stands, the majority of research has concluded that relative humidity essentially remains constant over time scales that are relevant for humans. However, current findings from the IPCC’s Fifth Assessment Report have estimated that relative humidity will shift slightly over the course of the 21st century due to rising surface temperatures attributed to climate change (IPCC 2013). This change in humidity will, generally, be characterized by decreases in relative humidity above land alongside increases in relative humidity above oceans, with a handful of exceptions.

The Arabian Peninsula is one of these exceptions, where relative humidity is projected to increase by between 1 and 5 percent, most noticeably in the countries of Yemen and Oman. However, across the rest of the Middle East, relative humidity will most likely decrease by less than 4 percent (IPCC 2013). These findings were corroborated by the results produced by the Global Climate Model, which projects a noticeable increase, to the tune of several millimeters per day, in both

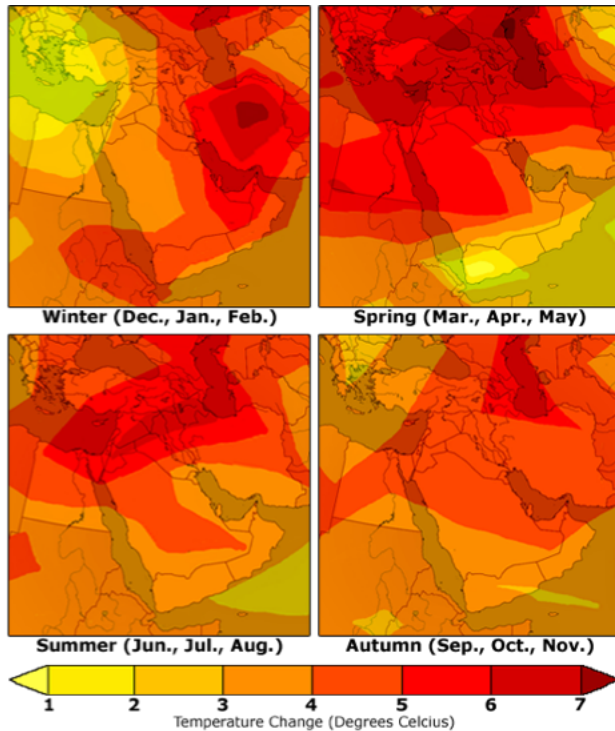


Figure 1: Projected temperature increases from 2019 to 2100 under current “business-as-usual” climate warming predictions (RCP8.5). Temperatures increases measured by month, with: Winter (1a) defined as December, January, and February; Spring (1b) defined as March, April, and May; Summer (1c) defined as June, July, and August; and Autumn (1d) defined as September, October, November.

precipitation and evaporation in the Arabian Peninsula. For the purposes of this article, the principal importance surrounding precipitation and evaporation is that the two increases will ostensibly cancel each other out, corroborating outside evidence that air humidity will not change radically.

This increase in humidity in the Arabian Peninsula can be attributed, in part, to wind patterns in and around the Persian Gulf. As northwesterly Shamal winds blow across the Arabian Peninsula and Iraq from the Persian Gulf, they will bring moisture to the coastlines of Saudi Arabia, Iraq, and other countries in the area.

Elsewhere in the Middle East, minimal increases—and in some cases, decreases—in precipitation coupled with increased evaporation are projected, which has the potential to lead to drying soil and, ultimately, droughts if these evaporation increases surpass precipita-

tion increases (IPCC 2013).

Wet Bulb Temperature

In modern times, wet-bulb temperature has never exceeded 31°C (87.8°F); however, an average warming of 7°C (44.7°F) around the world would almost certainly leave several regions around the globe uninhabitable. It is especially likely that the Middle East will be among the first regions of the world which reach this threshold, due to the combination of already high temperatures and humidity in the region. If climate change continues to follow an RCP8.5 pathway, then large swaths of the Middle East will almost certainly become uninhabitable by the end of the century, with even a larger percentage of the region suffering from extremely warm temperatures and the consequences associated with it (Pal and Eltahir 2015).

The results of this research already support a drastic increase in wet-bulb temperature due to rising surface temperatures and generally consistent humidity levels. If current projections continue, then numerous heavily populated cities along the Persian Gulf, including Abu Dhabi and Dubai—with a combined population of nearly 6 million—will exceed the 35°C (95°F) survivability threshold multiple times before the end of the century (Pal and Eltahir 2015). These cities are not alone, more Gulf-bound cities, including Doha in Qatar, Dhahran in Saudi Arabia, and Bandar Abbas in Iran will all exceed the threshold at least temporarily by 2100, casting the fate of over 1.5 million additional people into question.

Discussion and Conclusion

Looking back to the Middle East during the Islamic State's peak in 2014, the widespread territorial conquests and strength of the group is due in no small part to its ability to exploit a changing climate in the Middle East for its own objectives. Through exploiting the vulnerability of those suffering from deteriorating social, economic, and environmental conditions, the Islamic State was able to establish itself as an international threat, ruling over a territory of 282,485km² (109,068mi²), a caliphate with enough land to rival the United Kingdom. The Islamic State's proficient use of the climate in pursuit of its own ends points to a clear future—one where climate change and terrorism will continue to be inexorably linked well into the 21st century.

Although climate change may not be a direct cause of terrorism—

just as poverty is not a direct cause of crime—this study demonstrates its significant influence on a terrorist group's ability to recruit members and pursue its objectives. Should climate change continue along an unmitigated “business-as-usual” path, much of the Middle East will become, in all practicality, uninhabitable due purely to heat stress. The areas of the Middle East which avoid this will become subject to severe environmental strain, including shortages in water, food, and other necessary resources. As conditions in rural areas rapidly deteriorate, the new underclass will be forced to seek refuge en masse. Should these mobs of impoverished citizens flee to the cities, the aforementioned resource scarcity would be exacerbated.

Across the Middle East, especially in Syria and Iraq, we can already observe that governments are ill-equipped to alleviate the suffering of their citizens during times of crisis. Moreover, outside of major cities, authorities in these countries are rarely capable of providing even the most basic welfare for their citizens. Regardless as to whether this is symptomatic of an unwillingness or an inability to render aid, it is clear that many governments in the Middle East are ill-equipped to support their populations in the event of the major climate changes outlined above. In addition, we have already seen in the region that when governments cannot provide for the welfare of their citizens, those citizens begin to turn to alternative sources for this welfare (Schwartzstein 2017). At the moment, this alternative source of welfare has been the Islamic State and similar terrorist groups. In the wake of the lengthy U.S. occupation of Iraq—including subsequent civil strife—the Iraqi government had been too weak to compete with the Islamic State at its height. Throughout its peak year of 2014, the Islamic State held enough wealth from various enterprises to pay its fighters between \$400 and \$1200 per month, with additional bonuses based on a members’ number of wives and children (Pagliery 2016). At the same time, an average worker in Iraq could only hope to earn approximately \$500 to \$600 a month (World Bank 2014). Even during the Islamic State’s decline in Iraq and Syria, the group was still capable of paying its fighters up to \$600 a month, a substantial amount still (Pagliery 2016).

Studying this system through a mesodynamic lens, the Islamic State’s use of its resources to appeal to the essentially universal goal of accumulating wealth expanded its potential pool for recruits. Even if many of those on the Islamic State’s payroll did not necessarily

believe in the radical brand of Islam espoused by the group, it was apparent that joining the Islamic State was the preferable means by which to achieve personal goals. It would be easy for groups similar to the Islamic State to exploit this in the type of world projected under a “business-as-usual scenario.” With millions under threat of becoming now-homeless members of the underclass and even more suffering from a lack of basic necessities, a terrorist organization could build a strong foundation of supporters through economic means alone, drawing from the most vulnerable class of disillusioned and disenfranchised citizens.

Across the Middle East, even countries free from civil conflict struggle to provide adequate welfare for their citizens, with a “business-as-usual” scenario future unlikely to improve this situation. Meanwhile, terrorist groups have become quite wealthy through backing from foreign donors—both at the individual and state level—as well as through other means (Zehorai 2018). While some groups, including Hezbollah and Hamas, rely on countries such as Iran for their funding, other terrorist organizations have used the drug trade and human trafficking to fund their operations (Zehorai 2018). The Islamic State, however, has been able to fundraise in an alternative way. Acting as a fully functional and independent authoritative body, the Islamic State rose to be among the most powerful and wealthy terrorist groups through its bureaucratic management of the territory it had conquered. Levying taxes on its citizens and collecting income from oil fields and mineral fields brought the Islamic State more than \$3 billion in revenue each year at the group’s height (Zehorai 2018). With such wealth, it is not surprising that the Islamic State was capable of replacing the government in large areas of Iraq and Syria as the principal provider of welfare to the population. This problem will certainly continue into the rest of the 21st century, with governments neglecting their obligations to their citizens and terrorist organizations seeing power vacuums to fill.

However, equally as frightening as the prospects of what governments will fail to do in response to climate change is what governments will do. The principal concern in this regard is how willing governments will be to retaliate against their populations and to what degree this retaliation will affect civilians. As governments realize they are ill-equipped to handle the strain induced by climate change, then those in power may, in the words of theologian John B.

Cobb Jr (2002):

...find that a greatly reduced population would be preferable. The underclass will appear not only as superfluous, but also as an impediment to the well-being of those people who are productive. If, in desperation, the underclass turns to violence, then the powers that be will have the excuse they need to eliminate many of its members. (p. 12)

Throughout the Middle East, the underclass is already turning to violence, and governments are already retaliating in turn. This has been seen extensively in the war against the Islamic State, with the Iraqi and Syrian governments both retaliating heavily against Sunni populations in the territories under the control of the Islamic State, regardless as to whether these Sunnis were sympathetic to the Islamic State or not (Sly 2016). It is this disregard for human life in the ongoing fight against the Islamic State which exemplifies Cobb's aforementioned theory. Ultimately, as conflict over limited resources becomes more frequent and severe, governments may decide that harsher retaliation is not only preferable, but necessary. The War on Terror has already exacted a heavy toll on civilians in the Middle East. Several hundred thousand have died in Iraq alone from the conflict, with more dying every day. IEDs, drone strikes, and heavy artillery shelling have all contributed heavily to this statistic. Meanwhile, research has shown on countless occasions that the civilian casualties of counterinsurgency operations are among the most powerful forces which promote terrorist ideologies (Vertigans 2011).

Although the actions of terrorists are reprehensible, there is no doubt that terrorist motivations do typically arise from legitimate grievances. Poverty, victimization, and humiliation are all powerful motivators for individuals to reject political institutions and embrace organizations that promise more. It is these conditions that give rise to terrorism, and it is the exacerbation of these conditions promised by climate change that will ensure that terrorism will continue to be a threat far into the 21st century.

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FIDDLER'S TEVYE: THE BALANCE OF TRADITION AND CHANGE

Alexander Chang

Abstract

This paper explores the character development of Tevye in Jerry Bock and Sheldon Harnick's musical *Fiddler on the Roof* (1964) and his similarities with the play's subsequent adaptations since its conception. This paper draws on primary sources including the original libretto, newspaper articles, critical reception and interviews from *Fiddler's* opening, including video interviews with members of the original cast. The essence of Tevye as a character is that of a conflicted father who must learn to balance new conflicts while honoring traditions he cherishes. Preservation of the shtetl lifestyle is tricky for Tevye as his three daughters push his moral limits in regards to what he will allow for his family over time. That same conflict is mirrored in many *Fiddler* productions that relate to modern audiences, but still maintain the original play's intent or meaning. Other productions such as an all-black or Yiddish production of the play preserved stories of love with a modern cast while raising questions of culture and identity. Allusions to the refugee crisis in the 2015 production kept the original stories but subtly related it to modern issues.

Jerry Bock (1928-2010) and Joseph Stein's (1912-2010) Broadway musical *Fiddler on The Roof* (1964) examines the delicate and often tumultuous balance of tradition and change with the story of one man's own struggle. *Fiddler* demonstrates how Tevye, a devout Jewish man can retain his deep faith while still accepting change in both his secular life and in the ways he exercises his beliefs. Notably, this motif of tempered growth also emerged in the musical's development since its debut in 1964. As revivals of *Fiddler* are performed for changing audiences, the musical itself has evolved in ways, while still preserving the original intent of the creators. Just as Tevye struggles to maintain Jewish traditions while being pressed to adapt to modernism, revivals of *Fiddler* have fought to stay true to the original production while finding ways to connect to modern audiences.

Set in 1901 in a Jewish shtetl called Anatevka in Tsarist Russia, *Fiddler* opens with Tevye, a devout Jew and poor milkman who works to provide for his five daughters. In the early 1900s, Jewish shtetls like Anatevka were common across Europe (Zollman, n.d.). These communities were built on the firm foundation of remembrance and religious traditions (Zollman, n.d.). In the musical's prologue, Tevye exclaims "without tradition our lives would be as shaky as a fiddler on the roof!" As "Tradition," the opening musical number, explains, "the role of God's law in [Anatevka provides] balance in the villagers' lives" (MTI, 2019). In Tevye's song "If I Were A Rich Man," he boldly proclaims to God his desire for wealth and for the ability to comfortably provide for his family while studying the Torah, rather than living in poverty and tending to his farm. Soon, however, his dream, along with the balance described in "Tradition," is challenged. Tevye discovers he must sacrifice aspects of his faith that were once essential to him in preserving stability within his family in Anatevka. His desire for a life where tradition is strictly followed within his family is soon tested in connection with his each of daughter's marriages.

Tzeitl, the eldest daughter, refuses to marry the man selected by the village matchmaker, even though Tevye had already agreed. Traditionally, once a Jewish father gives his blessing for a match, his daughter must follow through and marry. However, Tzeitl insists on marrying her true love Motel. For Tevye, the idea of breaking this long-standing code of conduct is almost inconceivable, but when he sees the love between Motel and Tzeitl, he realizes he cannot sentence

his daughter to an unhappy marriage. To convince his wife Golde that the matchmaker was wrong, Tevye describes a fictitious nightmare that Golde's dead mother insists on Tzeitl marrying Motel, in "Tevye's Dream." Golde respects tradition as much as Tevye does, so if her mother insists on a new marriage, it must be true. After convincing his wife, Tevye then breaks this long-standing tradition and gives his blessing for Tzeitl to marry against the matchmaker's match.

Tevye's second daughter, Hodel, had fallen in love with Perchik, a boy who planned to return to Kiev to work toward the ongoing revolution in Russia. With the understanding that Hodel and Perchik likely will not ever return to Anatevka, Tevye must choose to let go of the tradition of families living together cradle to grave within their shtetl. Tevye must also physically let go of his daughter and trust God to protect her in her ventures in Russia. In "Tevye's Rebuttal," a soliloquy given after Hodel asks for his blessing and permission, Tevye exclaims "what's happening to the tradition / one little time I pulled out a thread / and where has it led?" (Harnick, 1964 pg. 72).

His third daughter, Chava, had been secretly fell in love with the young, rebellious Christian boy Fyedka. When Chava eventually asks for her father's blessing to marry Fyedka, expecting cooperation given her older sisters' marriages were allowed, Tevye refuses. To Tevye, marriage with someone outside the Jewish faith is a tradition he cannot break. Ultimately, Chava believes she does not need her father's blessing and elopes with Fyedka, understanding she may never be accepted into Anatevka again. In a final attempt to make amends with her father, Tevye refuses to speak with her and declares, "Chava is dead to us!" (Harnick, 1964 pg. 87) Tevye's decision to allow, and disallow, the irregular marriages of his three daughters in the name of love and tradition, are the clearest examples of Tevye's progression as a man still faithful to God but adapts to what is required of him in order to love his daughters well. Ultimately, Tevye is able to make principle changes that, while difficult, do not undermine what he believes in. Instead, Tevye's progression builds upon his faith and reinforces his sense of self. As an aesthetic medium, *Fiddler on the Roof* maintains a similar self-consistency even as its productions have evolved over time. From afar, *Fiddler* is a dramatic representation of Jewish shtetls and their populations in the early 1900s. At its heart, however, *Fiddler's* representation of Jewish culture displays universal themes of love, transition, and tradition that connect all cultures throughout

time. Based on the short stories “Tevye and His Daughters” by Sholem Aleichem, the first libretto of *Fiddler on the Roof* did not have the modern title widely recognized today. The *Old Country* was fifty-five pages long and purely focused on Tevye and his relationship with his daughters (Stein, 1961). A year later, the play was renamed *Tevye*, an acknowledgment to the character who embodies the central conflict (Stein, 1961). By the time Bock and Harnick’s version opened on Broadway in 1964, the musical’s title had changed to *Fiddler on the Roof*. Although its focus on Tevye’s delicate balance remained, the rewritten show featured stories about the community of Anatevka. Bock and Harnick used a unique process while writing *Fiddler*, grounding themselves in the idea that “the book always [comes] first” (Shukret, 2015). Accordingly, they were committed to preserving the voices of the characters in “Tevye and His Daughters” in each musical number and line of dialogue.

When choosing what stories to include in the play, Harnick and Bock decided to focus on three of the five daughters’ stories from the original text, rather than all five, as the two authors felt the stories of Tzeitel, Hodel, and Chava best represented Tevye’s conflict (Reside, 2014). Moreover, the realism in director and choreographer Jerome Robbins’ (1918-1998) depiction of the Jewish shtetl Anatevka further illustrates the importance of tradition—in this case, historical—to the musical’s creation. When asked about how an explicitly Jewish musical was so successful on the mainstage, Harnick credited director Jerome Robbins who was “obsessed, by this world, by this material. His research was endless...[and] the opportunity to recreate that shtetl world [gave] it another 25 years on stage” (Shukert, 2015). Legendary Broadway producer Harold Prince (1928-2019) was offered to direct *Tevye* originally but passed it on to Robbins. Though Prince originally claimed the play was “fascinating, but alien” (Oster, 2019), though now, through his collaboration with Robbins, Prince, now deceased, is celebrated for his role in *Fiddler*’s ode to Jewish history.

Throughout *Fiddler*’s development, creators also strove to safeguard the authenticity of Tevye’s character. In a 1981 interview, actor Hershel Bernardi (1923-1986) —who played the role of Tevye “702 times on Broadway over three years, starting in November 1965” (Saxon, 1986)—discusses his personal connection to his character. Bernardi’s religious and cultural background echoes that of Tevye’s in Anatevka, adding to the power of his casting.

Bernardi (Norton, 1961) describes how Tevye's anchor is God; his faith is a tradition he cannot break with:

When [Tevye] makes his decisions of traditions, [Tevye says to himself] 'I can't do this, I cannot break this tradition, my daughter being in love with the tailor or my daughter running away with a man in Siberia.' When he does that...he looks to God and says, 'what about this?'... give me an inspiration, tell me something that says I have to either stick with tradition or break. God is up there doing this. God is doing this and so that ...[eventually] 'I'll go through the middle'. I'll try to work around the middle which is a survivor's approach to living. You try to get around the middle...don't shake the boat too much and that is Tevye's essence. He eventually ends up being completely destroyed, but the fact is he is always trying to work through the middle.

As Bernardi points out, capturing Tevye's unabating desire to maintain order in a rapidly changing environment was not difficult, as it is a natural feeling Bernardi himself held as well.

Even as Fiddler adaptations perpetuate the sacredness of tradition through an emphasis on protecting the characters' original voices, creating historically realistic settings, and casting ethnically similar actors, the play has also had to adjust to new audiences and social sensitivities. Since its 1964 Broadway debut at the Imperial Theatre (Hernandez, 1964), Fiddler has toured off-Broadway, across the country, and internationally, continuing to be performed to this day. The theatre licensing agency, Music Theatre International, MTI, must grant a production license for any performance of Fiddler and it requires each production to maintain certain standards for the play. For instance, Anatevka's portrayal as a society rooted in Jewish tradition and Tevye's story arch are two immutable elements found in all adaptations of Fiddler. As the musical has become an iconic, historic show, there is little liberty given to alter the show's traditional presentation; however, modern version capitalizes on finite room for innovation to relate to current audiences while honoring its history.

Musicals that run for decades after their debut commonly receive changes—sometimes with mixed responses. Indeed, “long-ago creations are often radically reimagined without

incident" (Paulson, 2015), but, in 2015, the sixth on-Broadway production of *Fiddler* received an update that caused a sizeable stir within the theatre community (Deutsch, 2016). In this revival, an unnamed man opens the show wearing a modern-day bright red parka, holding a book, and speaking the iconic words from the prologue: "A fiddler on the roof. Sounds, crazy no?" (Harnick, 1964 pg. 1). The man then transforms into Tevye, taking off the jacket to reveal his period-appropriate, traditional clothes and a prayer shawl. The show's finale mirrored the modern opening act, with Tevye wearing the same red coat and exiting the stage in a line of refugees, representing immigrants today who evacuate their homeland for refuge in America (Paulson, 2015). The show's director, Bartlett Sher (1956-present), was "adamant that the revival should explicitly, if briefly and quietly, connect to current events" in America, namely the debate on immigration laws and who is or is not allowed to enter the country (Paulson, 2015). The revival received backlash from Harnick, *Fiddler*'s original writer, who would have preferred to see the play's historical authenticity maintained in the 2015 production. He repeatedly objected to allusions to modern issues, "leery of any changes to a show that has totemic power for several generations of theatergoers" (Paulson, 2015). Although Harnick may have had the power to prohibit the change, he was eventually persuaded to accept it by positive audience feedback. He explained in an interview, "[to] my surprise, it had an extraordinary reaction from a significant part of the audience that finds it very moving [as expressed through] written letters to the producer [and] the cast" (Paulson, 2015). Although the core story of *Fiddler* remained untouched, the addition of refugees journeying to America in the finale drew a closer connection to modern *Fiddler* audiences who face similar conflicts today.

Fiddler has been used as a medium to express community concerns in additional ways. In 1968, in the poverty-oppressed, African-American community of Brownsville, Brooklyn, musical-drama teacher Richard Piro had a vision for his young students to perform *Fiddler* as an escape from chaos revolving around race relations in their neighborhood. When the greater Brownsville community found out, many turned against Piro and the students, "alerting the producers that they didn't have official permission" (Brawarsky, 2013). After a short deliberation, Bock, Harnick, and Harold Price, the producer, agreed "that despite the rigid rule forbidding amateur productions,

this production deserved [their] support and approval” (Piro, 1971, p. vi). Despite the difficulties of convincing the general public and school board to support the production, Piro was adamant that *Fiddler* would benefit the community, expressing to a student “I’m going to fight this thing through even if you knock my teeth out in the process” (Piro, 1971, p. 93). The real-life struggle of Piro and his students parallels the oppression *Anatevka* faced by the Bolsheviks. Eventually, the all-black amateur production of *Fiddler* came to fruition and quickly became national news. The performance aired in conjunction with an ABC-TV informational documentary “Black Fiddler, the Negro and Prejudice” (Fleischman, 1969). It became a symbol of unity and hope across the country, especially because it was performed in a time and place riddled with hate. In the introduction of Piro’s novel “Black Fiddler,” Stein wrote that the all-black production “serve[d] as a small tool to help heal the breach, to emphasize the parallels between the [Blacks and Jews, and] the similarities in their history, their traditions” (Piro, 1971, p. v). The all-black production of *Fiddler on the Roof* demonstrates that the traditional telling of *Fiddler* can be retained and used as “a part of an evolving community culture... For the school, the community, and for New York City, Piro produced a moment of excellence and magic” (Piro, 1971, p. xii).

No other modern production encapsulates the essence of evolution and tradition than Joel Gray’s (1932-present) Yiddish production that ran off-Broadway in New York City from February 2019 to January 2020 (Broadway.com, n.d). Gray, whose father was a Yiddish comedian, was inclined to direct the National Yiddish Theatre Folksbiene’s production of *Fiddler* without speaking the language due to his love for the play (Rothstein, 2019). In an interview with *Playbill*, Joel explains how the spoken language of Yiddish in his adaptation roots the play in Jewish history while simultaneously is celebrated by and connects with modern audiences today:

“Yiddish was the *mamaloshen*, the language of our mothers, that was so pure. To hear it, to have it set out there on the stage, openly, when in the past people would make fun of Yiddish, or not want to associate themselves with it in order to feel safe or to feel American...is now a balm. It’s a balm to hear it spoken openly, freely, funnily, heartbreakingly, and to know that it’s the real thing. The musical is about survival. And family. Its [theme of immigrants flee-

ing violence] is about everything that is going on in the world even today. There are all these political events, and [the synagogue murders in] Pittsburgh, all these things going on that are awful and frightening. There's a lot of fear around. The show has to do with the paternalistic wisdom that was the essence of Tevye, who loved his children and loved his life but was aware that danger was not far away. Not unlike today."

Gray's culturally centered adaptation celebrates Jewish practices while maintaining the virtues of love and tradition. The Yiddish production reimagines Bock and Harnick's original vision for *Fiddler* adding authentic elements and modifications that reconnect audiences to the play in a new light. Although there are certainly many revivals of *Fiddler*, as we can see, each time it is revived it raises issues of personal conflicts, remembrance, and unconditional love.

True to his Jewish faith—which is grounded in the importance of remembrance, from holidays like Passover and Purim, when Biblical stories are retold, to Shabbat, when people reflect on God's graces—Tevye is grounded in Jewish tradition. Though he must learn to change, he is able to re-confirm his religious identity, maintaining his self-authenticity. Similarly, each of *Fiddler*'s revivals has, and continues to, find ways to honor its foundation in history and its original manuscript, while still finding ways to transform aspects of it to appeal to changing audiences and societies. Each staging of *Fiddler* must find its own balance of history and modernity, just as Tevye—and the fiddler—tried to find his.

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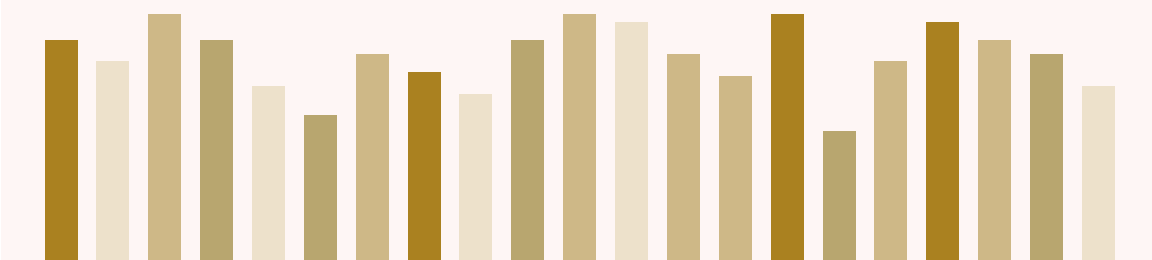


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CREATIVE WORK

CATHERINE COSGROVE

Before writing “Wiehle,” I studied the styles of unstructured poetry utilized by contemporary poets. In particular, studying writers such as Ocean Vuong and Joan Didion showed me the strength punctuation and enjambment in personal writing. “Wiehle” is an examination of my own personal identity, coping with the loss of a mother, and the community in Northern Virginia I grew up in early in life. The aim of this work is to examine the mundane things which stick with us amidst periods of change.

WIEHLE: AN ELEGY FOR WHAT WAS

There are always signs of the times:
the backpedaling of brakes, the compression
of clovers beneath the sun and the sweat and
all the unimaginable impressions you long to depart from.

It comes in the simplest ways, it comes
without warning: copperheads
nipping at your ankles, though your parents long warned
you of the snarl of this trail,

the splintered wood of your deck, the hill
where you taught yourself to ride a two-wheel bike
because everyone else was busy, and because
you wanted to be strong, because you thought this was how.

The creeks where you swam with an urgent
sense of freedom, a careless nature of sledding
downhill, across icy ponds, across slushed up puddles.
The stairs. She is buried

in a state eight hundred miles away
and when these pleadings and restless chasings begin
you remember the reflection of light across the stackable chairs
on Sunday afternoons — because

they could not afford church pews — because Sunday
would soon just be another day. You remember
the smell of sunscreen on an October night because your
knees knocked the bottle over on the way home

from the hospital, unfazed to watch the Phillies
raise their second pennant from the floor
of a kitchen that was not yours.
Of the staircase

and credit card bills and the circling rage of echoing
walls where she believed you
to be asleep, to be safe, to be ignorant
and innocent and composing a painting of what love should be -

COSGROVE

not of how to hurt and suspect and reason with yourself
whether it is worth it to feel
how you feel, to ache as you ache.
There are always signs — An election shirt someone

you did not live to see inaugurated, a stocking
you did not live long enough to have filled.

There are signs.



ANISHA GUPTA

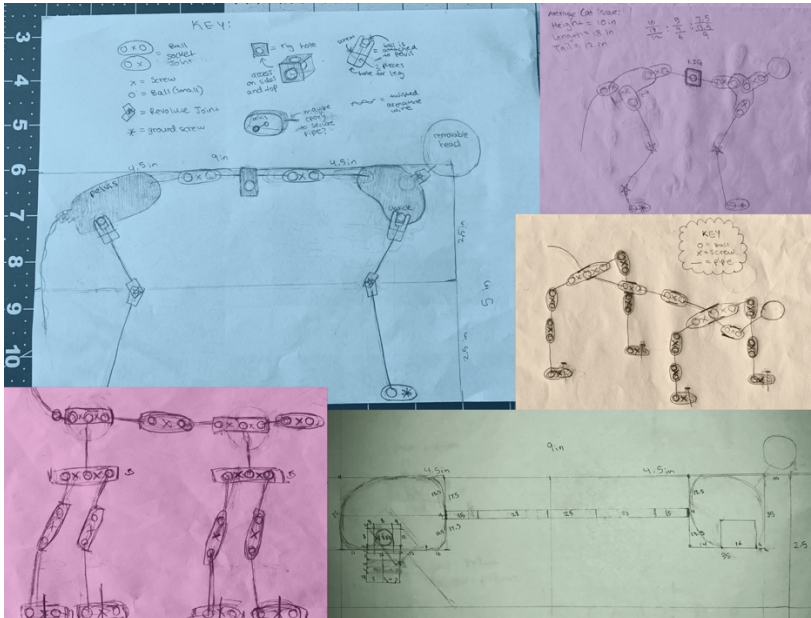


Photo 1: Armature Design Sketches



Photo 2: Assembling the Joints

An armature is a skeleton for a stop-motion puppet. The flexibility of armatures is what allows stop-motion characters to move and come to life. The most popular types of armatures are wire armatures, and ball and socket armatures. Typical ball and socket armatures are incredibly expensive and not very customizable. 3D printing is being used in stop-motion for everything from face replacement to prop design. In this project, I set out to use 3D printing in a new way, to design an inexpensive but functional ball and socket armature. I documented my rapidprototyping experiments on my blog, www.anishagupte.com, where I aimed to create an armature for a stop-motion kitten. To gain insight on the stop-motion process, I interviewed stop-motion industry professionals at major film studios such as Laika and Stoopid Buddy Stoodios.

First, I studied the anatomy of cats. I collected pictures and videos of cats in motion to determine which joints and body parts were most important for my armature. I also studied popular stop-motion films and their armature designs. Next, I created a series of sketches for the armature models. I modeled different pieces using the software, Autodesk Fusion, and printed them at the FSU Innovation Hub. A series of prototypes were required to create functional pieces. My greatest challenge was maximizing stability without sacrificing mobility. For instance, the joints needed to be able to both move and stay in place for long periods of time during filming. Furthermore, the stop-motion cat needed to not only stand on its own, but also balance with a paw off the ground mid-walk cycle. My finalized set of pieces consisted of a ball joint for the back, foot joints, knee joints, neck joints, a pelvis plate, and a chest plate. I secured each joint with screws, wing nuts, and nylon washers, and assembled everything with liquid epoxy. The pieces were also spray painted with a rubber coating for added friction. I sawed brass pipe and soldered them to brass balls to create the bones. Ultimately, I was successfully able to use 3D printing to create a pair of armature cats for my stop-motion film. My film, currently titled, *Catitude*, is about two kittens who live in the sky, one with lightning powers, and the other with thunder powers. When Thunder Kitty can't sleep, she wakes up her grumpy sister, who takes some shocking action! My goal in future projects will be to continue to push the boundaries of 3D printing to create better, more customizable, lightweight armatures for all types of characters, from humanoids to imaginary creatures.

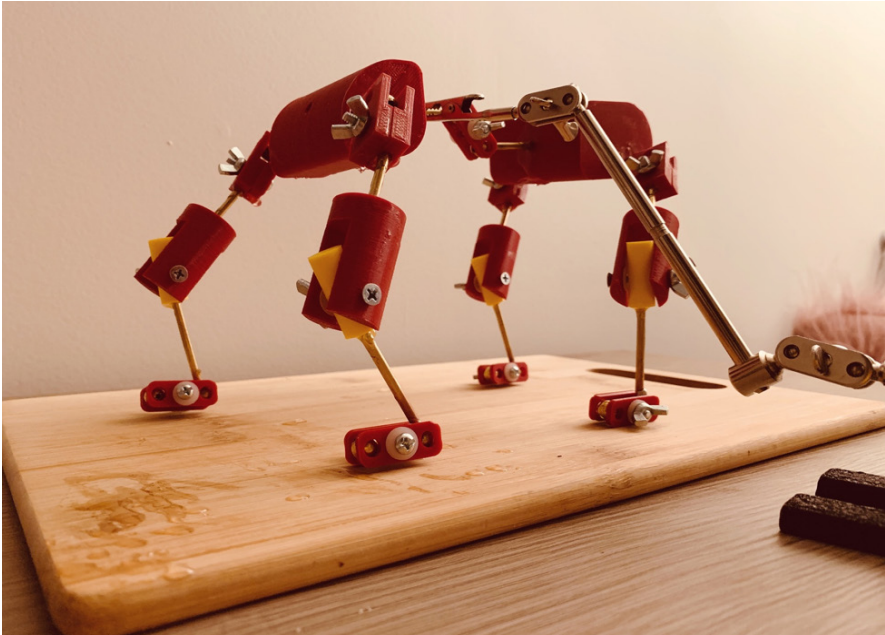


Photo 3: 3D Printed Armature

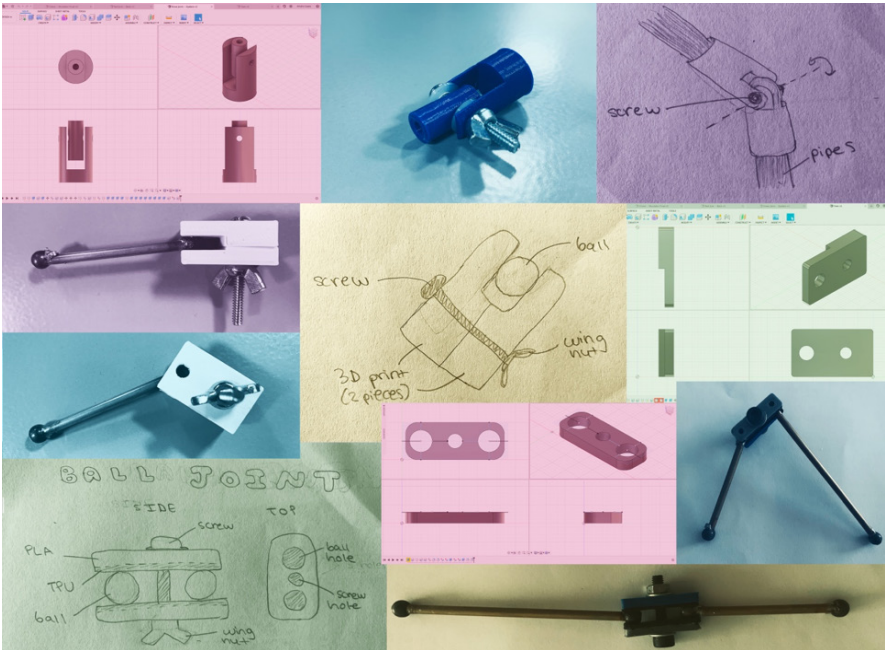


Photo 4: Modeling the Joints



See more of Anisha's project, including interviews with stop-motion industry professionals and videos of her creative process, on her blog at: www.anishagupte.com



Building an Artificial Language from Scratch: Joejuca

Juan Coste Delvecchio, Caleb Unold and Joel Weeks

Constructed languages, otherwise known as conlangs, are languages that are artificially created to serve some purpose. Dothraki and High Valyrian in *Game of Thrones*, and Quenya in Tolkien's *Lord of the Rings* are some well-known conlangs. This paper describes a novel conlang, Joejuca: created for fishermen and sailors in the fictional world of Coweun. Joejuca is used in this fictional world for communication of people that speak different native tongues. Because in its fictional world Joejuca achieves communication between people speaking different languages, similar to conlangs like Esperanto, it is also an auxiliary language, or an auxlang. Joejuca was constructed as part of a class project. It was partly inspired from a pidgin (a simplified form of language between two peoples with different languages as a means of communication) which arose between Basque whalers and Icelanders in the 17th century (see for example Etxepare and Miglio, 2015). Our language sought to build on a similar concept, but with a more fully fleshed out linguistic system.

The fictional area in which Jøejuca exists was once a large collective landmass in the middle of an ocean world, with many different peoples under one language and culture. A severe and violent volcanic eruption destroyed the landmass and sunk much of it with floods, and a large island surrounded by other small islands would come to be the new homes of the previously unified people. Having been set back to square one technologically by the volcanic eruption, civilizations started over; each island slowly split away from the original shared language, and after much time had passed, each island and new developing civilization had developed its own unique and distinct language. Still, each island civilization focused on fishing as a means of sustenance and commerce. Eventually, when technology developed further, allowing the civilizations to reconnect with each other through boats, the civilizations attempted to trade with each other only to find that it was extremely difficult without sharing a common language. So much time had passed that the individual languages that had deviated too far from the original languages and communication between island civilizations had become nearly impossible and took great effort. Yet, trade with other civilizations was of great importance to every island and the islanders were determined to be able to communicate with each other by some means. Thus, the need for an auxlang arose, and Jøejuca came to be the method of communication between the islanders.

Jøejuca, being developed as a fishing auxlang, has most of its vocabulary and verbs focused around fishing, fishing accessories, fishing actions, and other fishing related things. When developing the auxlang, this was kept in mind in order to try and maintain the authenticity of the auxlang and its functionality for the imagined sailors and fishermen that use it.

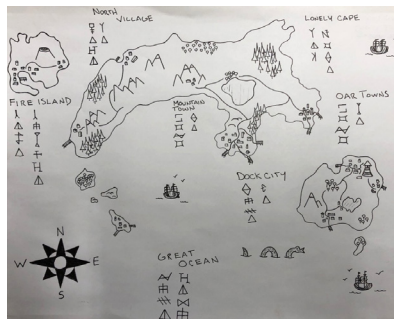


Figure 1: World Map

Figure 1 depicts the map of the fictional world of Jœjuca, including the volcano that destroyed much of the islands and flooded the rest of the land (top left), the many islands around a central island, and the many docks around all of the cities and settlements, which show the importance of fishing to the inhabitants of the islands. Furthermore, the different cities and settlements depicted in our map have their accompanying translation in Jœjuacan script directly below them as a visual aid. This script will be discussed in more detail in section 4.

The Sound System of Jœjuca

This section describes and exemplifies the phonological system of Jœjuca, i.e., its vowels, consonants, syllabic structure, and stress system. All of the following linguistics characteristics of the constructed language were molded to best fit the context in which the language exists. For example, many of the linguistic characteristics were created around the image of a sailor speaking a language that “sounds” like something that a sailor would use.

Jœjuca utilizes five different vowels: /a/, /æ/, /œ/, /u/, and /y/, as shown in the vowel chart in Figure 2, which follows the conventions of the International Phonetic Association (IPA, 2003).

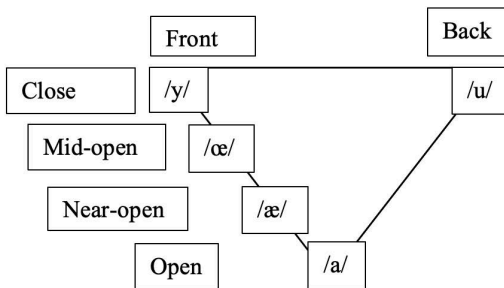


Figure 2: Jœjuacan vowel chart

The decision-making process for choosing these vowels for our conlang specifically was quite simple. Due to Jœjuca being an auxlang, we wanted similar vowels to those in some of the most widely spoken languages in the world, namely English, Spanish, and French. We borrowed vowels that we liked from these languages that we thought would fit to our imagined sailors’ voices and committed to them. Examples of minimal pairs for the five vowels in our language are provided in (1).

1. Vocalic minimal pairs

- /ly.ra/ 'bait' /lœ.ra/ 'nighttime'
- /mu.ru/ 'ship' /ma.ru/ 'cold'
- /kœ.ra/ 'cod' /kæ.ra/ 'grouper'

(see conventions section 1., 2., and 3.)

As seen by our minimal pairs in (1), Joejucan roots are not typically very long. Most words in Joejuca tend to be around two syllables long. Word length will be explored later on in the paper, as suffixes and prefixes are very common, and often stack making derived words longer than roots. For example, a word whose root is two syllables, but has an added prefix and suffix doubles the word length.

Joejuca uses 18 different consonants, 16 of which are pulmonic (i.e., pronounced with air coming out of the lungs, like most sounds in the world's languages) and two of which are non-pulmonic (i.e., pronounced with an additional non-pulmonic initiation). The 16 pulmonic consonants are /p/, /b/, /t/, /d/, /k/, /g/, /m/, /n/, /B/, /r/, /v/, /θ/, /ʃ/, /z/, /x/, and /ʎ/. The two non-pulmonic consonants are bilabial and dental clicks: /O/, and /l/. The full consonant charts for pulmonic and non-pulmonic consonants in Joejuca can be seen in Figure 3 below.

	Bilabial	Labio- dental	(Inter) dental	Alveolar	Post- alveolar	Retroflex	Palatal	Velar
<i>Clicks</i>	ɔ		ǀ					
<i>Stops (plosives)</i>	p b			t	d			k g
<i>Nasals</i>		m					ɲ	
<i>Trills</i>		ʙ			r			
<i>Fricatives</i>			v θ		ʃ	ʈ		x
<i>Lateral approximants</i>							ɭ	

The choices for the different consonants in Joejuca were made on a few primary criteria. One of the criteria was to include unique consonants that sound as if they could be part of English or Spanish, but sound slightly off, as if they did not belong. For example, Spanish includes the use of an /r/ trill, and we implemented a /B/ trill into Joejuca. Furthermore, we wanted a conlang whose word were full of stops and fricatives, hence the majority of our pulmonic consonants being stops and fricatives: 11 out of 16 of Joejuca's pulmonic consonants fall under that categorization. The reasoning behind including so many stops and fricatives was for an added touch of uniqueness to the language, and it was also how the group imagined the sailors

speaking to each other. The non-pulmonic consonants used were clicks, implemented in order to add a sense of uniqueness to the language. Throughout the world's languages, very few utilize clicks: less than two percent of languages include them in their sound inventory, and these are generally found in Southern/Eastern Africa (Maddieson 2013). Unlike clicks found in world's languages, however, clicks in Joejuca have a unique purpose, since they are used to emphasize and diminish certain words. For example, the word /xœxuka/ (Joejuca) in our language means 'fish,' but when a bilabial click is added to the end, for example, /xœxukaɔ/ the meaning changes to 'big fish' or 'a grand quantity of fish' depending on the context. Conversely /xœxuka/ would mean the opposite, as the dental click is meant to diminish words. Possible meanings could be 'small fish' or 'a small quantity of fish.' This small detail in our language, we believe adds a touch of uniqueness to the spoken element. Further information on the pronunciation of both consonants and vowels can be found on an online, interactive International Phonetic Alphabet chart created by Peter Isolato (Isolato, 2003). Minimal pairs for the Joejucan consonants are given in (2):

2. Consonantal minimal pairs

- | | |
|--------------------------|-----------------------|
| • /ʃuk/ 'sugar' | /ʒuk/ 'cold' |
| • /Bæ/ 'hook' | /ræ/ 'net' |
| • /vaʃa/ 'boat' | /θaʃa/ 'canoe' |
| • /kyka/ 'river' | /gyka/ 'tree' |
| • /ma/ 'mine' | /ɲa/ 'food' |
| • /tœ/ 'shoe' | /dœ/ 'whale' |
| • /ʒaBœ/ 'sails' | /xaBœ/ 'warm' |
| • /payuk/ 'north' | /bayuk/ 'south' |
| • /ʎeʃ/ 'east' | /ɲeʃ/ 'west' |
| • /xœxukaɔ/ 'large fish' | /xœxuka/ 'small fish' |

Syllable structure in Joejuca was developed from experimenting with different syllable lengths that we found visually appealing. As far as inspiration goes, we decided not to look for any guidance from other existing real languages or constructed languages, hoping to add uniqueness to our own constructed language. Basic syllable structure in Joejuca is CV(C)(C) (see conventions section, number 4.). Onsets (i.e., syllable-initial consonants) are always obligatory in Joejuca; never will a vowel be present without a consonant in front of it. An example of a one syllable word in Joejuca with just the onset and syll-

syllable is /tœ/ which translates to ‘shoe.’ Codas (i.e., syllable-final consonants) are also allowed, but are very seldomly used. An example of a word with a coda in Joejuca is /pɛʃ/ which translates to ‘west.’ Diphthongs, much like codas, are also allowed, but are fairly uncommon. An example of a word, or rather, a suffix with a diphthong is /kuœ/ which is the suffix added to nouns to indicate it belongs to the terrestrial class (section 3). Joejuca also utilizes contrastive stress, albeit rarely. Example of two different words that utilize contrastive stress are /pœu/ which translates to ‘island,’ and /pœú/ which translates to ‘fast.’ Stress in Joejuca always falls on the last syllable of the word, on the last vowel. For example, the word /rœ.kú/ ‘palm tree.’

The Writing System of Joejuca

Due to the fishing and business context of our fictional world, whatever writing system we designed would have to follow the basis for which the auxiliary language was created. So, what ultimately developed was a runic style alphabet writing system in which each phoneme (including clicks) corresponded to its own letter/rune. The alphabetic writing system can be seen in Figure 4 below:

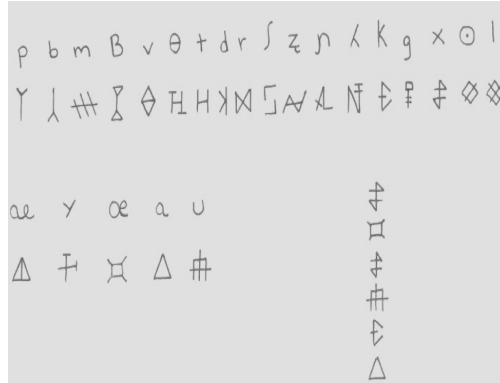


Figure 4: Writing System. Top row: Consonants. Bottom row: Vowels. Bottom column: the word ‘Joejuca’ written in our script.

We chose a runic style system for our alphabet due to how our language was mostly spoken between fishermen and sailors yet rarely written. After thinking about contexts in which fishermen and sailors would write, such as carving writings on the side of wooden boats, or wooden crates, or even on signs, it became clear that avoiding curves is the easiest way to carve into wood. Before coming up with the different glyphs for phonemes, inspiration was taken from different existing glyphs from world languages such as Lyndian and Old Turkic.

This led to the birth of a system with mostly rigid lines and no curves in order to fit the context in which our language exists.

The writing of Jœjuca in the bottom right in Figure 4 serves to illustrate how our script is written: from top to bottom.¹ An example of how our script is organized is as follows:

L	T
I	H
K	I
E	S

The development of our writing system certainly helped to envision the world differently. Before developing Jœjuca's unique writing system, the world we had envisioned was only imagined in a speaking sense. By adding a written element, contexts and mediums in which and through which the language exists change and add a new dimension to the language.

A Lexicon of Jœjuca

A mini-lexicon for our conlang was developed by using the Rosenfelder vocabulary generator ('Gen') approach available at <https://www.zompist.com/gen.html> in combination with other methods, such as creating words which sounded like they would fit in our fictional world. The Gen approach is a technique used to create words for a constructed language by inputting the constructed language's phonetic characteristics into a word generator, which outputs a word list. By using a word generator like Rosenfelder's, many word possibilities are created instantaneously, and meanings can be applied to the words as needed. This provided an efficient approach not only to constructing a mini lexicon that served as the basis of a sample fictional text in this language, but also to expand it for forthcoming writings and translation as needed. Also, Rosenfelder's Gen approach automatically syllabifies words, so cutting off excess syllables to create shorter words is possible, which makes for an even easier word creation process. The following is a list of 32 roots in our conlang which includes nouns, verbs, adjectives and adverbs (3). Most of the roots included refer to seafaring concepts. Note also that adverbs are derived from adjectives through the addition of the prefix /ʃu-/.

¹ When a line word in Jœjuca is finished, the next word begins to the right of the previous one and is structured from top to bottom as well. No spaces exist between words, as different columns serve to signify the beginning of a new word. Spaces however do exist under the columns. In addition, there are no different glyphs for capital letters, as there is no use for them in our language.

Sections 5 and 6 discuss how these roots are derived to express a range of morphological functions and meanings.

3. Joejuca roots

<u>Nouns</u>	<u>Verbs</u>	<u>Adjectives</u>	<u>Adverbs</u>
/xa.e.ka/ ‘fisheries’	/θœ/ ‘to cast’	/xa.θœ/ ‘slimy’	/fu.xa.θœ/ ‘slimily’
/Ba_ ‘oars’	/Bœ.xa/ ‘to boat’	/θuθ/ ‘gross’	/fu.θuθ/ ‘grossly’
/bæ.xa/ ‘islands’	/paθ/ ‘to row’	/væ.tu/ ‘incredible’	/fu.væ.tu/ ‘incredibly’
/nu.mæ/ ‘sailors’	/rœ.ku/ ‘to sail’	/zy.rœ/ ‘stupid’	/fu.zy.rœ/ ‘stupidly’
/By.θæ/ ‘fires’	/vud.Bæ/ ‘to sit’	/θy.vy/ ‘small’	/fu.θy.vy/ ‘smallly’
/zu.vu/ ‘sterns’	/du.væb/ ‘to watch’	/zu/ ‘peaceful’	/fu.zu/ ‘peacefully’
/fuv.py/ ‘houses’	/θæp.Bœ/ ‘to burn’	/ru/ ‘beautiful’	/fu.ru/ ‘beautifully’
/pæb.dat/ ‘families’	/tœ.bu/ ‘to walk’	/fœ.py/ ‘nice’	/fu.fœ.py/ ‘nicely’

Nominal Morphology

Joejuca encodes number and noun classes, but not case. As far as number goes, our language operates in a default plural, with various prefixes to denote the singular, dual, and collective. Specifically, the prefix for singular is /bu-, the prefix for dual is /ku-, and the prefix for the collective is /du-. For example, if we take the noun /nu.mæ/ ‘sailors’, we can add the appropriate prefixes to denote singular, dual (i.e., two), and collective (i.e., ‘all’) as shown in (4):

4. Numbers in Joejuca

- Default plural /nu.mæ/ ‘sailors’
- Singular /bu.nu.mæ/ ‘sailor’
- Dual /ku.nu.mæ/ ‘two sailors’
- Collective /du.nu.mæ/ ‘all sailors’

The use of the default plural is not uncommon in the world’s languages, which was our reasoning for choosing the default plural for our auxlang. Many of the world’s languages have an obligatory default plurality for all nouns (Haspelmath, 2013). Yet, English and Spanish do not utilize the default plural, which were two languages we wanted to intentionally distance Joejuca from.

Instead of differentiating among feminine, masculine and/or neutral nouns, as many world languages do, Joejuca distinguishes three distinct noun classes: the aquatic, the terrestrial, and the celestial. The aquatic noun class includes things that deal with or are related to water (such as boats, fishes, tides), the terrestrial includes things that

deal with or are related to land (trees, humans, villages), and the celestial includes all things dealing with the sky and other abstract concepts (death, thoughts, birds), along with anything else not covered by the terrestrial or aquatic noun classes. Noun classes like the ones chosen for Jøejuca have observable similarities with other constructed languages such as High Valyrian from *Game of Thrones*, created by linguist David Peterson. For example, High Valyrian uses lunar, solar, terrestrial and aquatic noun classes (Peterson, 2019). Noun classes are indicated by articles in our language, as exemplified in (5). All can be translated as ‘the, a, an’.

5. Noun class articles in Jøejuca

- Terrestrial: /œ/ /œ du.bæ.xa/ ‘all of the islands’
- Aquatic: /æ/ /æ bu.gæ/ ‘the tides’
- Celestial: /a/ /a ku.pa.ʃæ/ ‘the two suns’

Noun classes were chosen for Jøejuca not for their lack of popularity or uniqueness, but due to how well they fit within our fictional world: life in our world revolves around the ocean, so it made sense to create noun classes for aquatic things, terrestrial things, and celestial things.

As shown in the preceding section, adjectives are also present in Jøejuca. Yet, these adjectives do not encode number or noun class, which are denoted exclusively by the nominal prefixes and articles discussed above. Adjectives come after the noun that they modify (i.e., ‘boat large’ rather than ‘large boat’). One example is ‘incredible tides’: /bu.gæ væ.tu/. In addition, articles precede the noun; thus, ‘the incredible two suns’ would translate as /a ku.pa.ʃæ væ.tu/, where /a/ is the celestial article; /ku.pa.ʃæ/ is ‘suns’ (i.e. ‘sun-dual’), and /væ.tu/ the adjective ‘incredible’.

Pronouns in Jøejuca are straightforward in the sense that they are formed by combining the noun class article and the nominal number prefix. For example, the pronoun corresponding to a singular, terrestrial noun is pronoun /buœ/ (singular prefix /bu-/ plus terrestrial article /œ/). Other pronouns formed in similar ways are provided in (6) below.

6. Jøejuca pronouns

- Terrestrial Singular (Him/Her/He/She/It/etc.): /buœ/
- Terrestrial Dual (They/Them/Those/etc.): /kuœ/
- Celestial Collective (A Swarm/A Flock/etc.): /dua/
- Aquatic Singular (Him/Her/He/She/It/etc.): /bæ/

Verbal Morphology

Verbal morphology in Jøejuca is straightforward and geared to make the language as simplistic as possible. We chose against including agreement, mood, modality, or evidentials in our conlang in order to avoid adding unnecessary rules to complicate language learning for the fishermen and sailors who would be the primary users of the language. Instead, we chose to include both tense and aspect. In Jøejuca, there are three different tenses that are modelled and chosen after the context in which our language is spoken in: fishing and business. Thus, the tenses we chose are past business terms, the current business term, and future business terms. Tense is indicated by suffixes, which are provided and exemplified in (7) below:

7. Jøejuca tense

- Past business term: /-ku/
Example: /rœ.ku/ ‘to sail’ -> /rœ.ku.ku/ ‘to sail in a past business term’
- Current business term: /-mu/
Example: /paθ/ ‘to row’ -> /paθ.mu/ ‘to sail in the current business term’
- Future business term: /-bu/
Example: /Bœ.xa/ ‘to boat’ -> /Bœ.xa.bu/ ‘to boat in a future business term’

The chosen suffixes clearly connect to our world through the use of business terms as our chosen tense, as our auxlang is used for business communications. For example, if a sailor/fisherman refers to a past sailing/fishing expedition or a deal that occurred two days ago, and the current business term had been in effect for the past week and for another five days, then the sailor would refer to his deal as having occurred in the present, even if it had occurred two days ago.

Aspect in our language is also encoded, but through prefixes. The two aspects in our language are the perfective and imperfective, and work in accordance with the three tenses in order to create the past, present, and future perfective, and the past present and future imperfective. The default in Jøejuca is the present perfective and the rest are encoded through affixes. The past perfective is indicated by the /ky-/ prefix and the future perfective is indicated by the prefix /by-/. The present imperfective is indicated by the prefix /mæ-/, the past imperfective is indicated by the prefix /kæ-/, and the future imperfective is indicated by the prefix /bæ-/. Examples are provided in (8):

8. Aspect and tense in Jøejuca

- Past Perfective: 'a sailor sat' /bu.ju.mæ ky.vud.Bæ.vu/
- Present Perfective: 'a sailor sits' /bu.ju.mæ vud.Bæ.vu/
- Future Perfective: 'a sailor will sit' /bu.ju.mæ by.vud.Bæ.vu/
- Past Progressive: 'a sailor was sitting' /bu.ju.mæ kæ.vud.Bæ.vu/
- Present Progressive: 'a sailor is sitting' /bu.ju.mæ mæ.vud.Bæ.vu/
- Future Progressive: 'a sailor will be sitting' /bu.ju.mæ bæ.vud.Bæ.vu/

Morpheme shape in our language borrows from popular languages around the world in the sense that only concatenative morphemes are utilized, and non-concatenative morphemes are never allowed under any circumstances. As far as concatenative morphemes go, only suffixes and prefixes are allowed in Jøejuca, as there are no infixes or circumfixes to encode for any meaning. An example of a concatenative morpheme in our language is the prefix /du-/ which is used to signify the collective: /du.ju.mæ/ 'all of the sailors'.

The purpose for limiting verbal morphology to simpler, more common methods found in other popular world languages was to make the auxlang as similar to other languages as possible, and thus make it easier to learn for the fishermen and sailors interested in acquiring the language for trading purposes.

Sentence Structure

In Jøejuca, word order follows a subject-object-verb organization, which was chosen once again for the intentional simplicity that should come when designing an auxlang. SOV word order is the most common word order found throughout real world languages as well (Dryer, 2019). We also chose to do so because adjectives were decided in an earlier challenge to come after a noun, so following suit with verbs made the most sense. Negation in Jøejuca is encoded through the use of the particle /xæ/ before the verb it is negating. Examples of statements with and without the use of negation are given in (9):

9. Statements

- /œ bu.ju.mæ θæ.θæ.ku/ 'a sailor was cooking'
- /œ bu.ju.mæ xæ θæ.θæ.ku/ 'a sailor was not cooking'
- /œ juv.py θæp.Bœ.mu/ 'a house is burning'
- /œ juv.py xæ θæp.Bœ.mu/ 'a house is not burning'

Polar (aka yes-no) questions are also encoded through the use of a particle; however, the particle is present at the end of the phrase. The particle to encode a polar question is /ʃœ/. Examples of polar questions are provided in (10):

10. Polar questions

- /œ bu.nu.mæ θæ.θæ.ku ʃœ/ ‘a sailor was cooking?’
- /œ juv.py θæp.Bœ.mu ʃœ/ ‘a house is burning?’

Similarly, negative polar questions combine the negation particle and polar question particle in a single phrase. To structure a negative polar question in Joëjuca, one must add the /xæ/ particle before the word and include the /ʃœ/ particle at the end of a phrase. Examples of negative polar questions are given in (11):

11. Negative polar questions

- /œ bu.nu.mæ xæ θæ.θæ.ku ʃœ/ ‘a sailor was not cooking?’
- /œ juv.py xæ θæp.Bœ.mu ʃœ/ ‘a house is not burning?’

Content questions are simple to structure as well, as all that needs to be done is switch the word order from subject-object-verb to subject-verb-object, followed by an interrogative pronoun at the end of the phrase to clarify the response that should be given. Interrogative pronouns in Joëjuca are /ʃœ.vu/ ‘who,’ /ʃœ.mu/ ‘whose,’ /ʃœ.bu/ ‘what,’ and /ʃœ.lu/ ‘which.’ Commands are indicated by the presence of the particle /kœ.kœ/. There is only one type of command in Joëjuca, as the language is strictly for business and there is no point in overcomplicating business with politeness and/or status.

Fictional Text

As a final, more complete demonstration of the language in action, the following is a fictional text about a sailor on his boat. The following fictional text is glossed and translated according to Leipzig Glossing Conventions (available at <https://www.eva.mpg.de/lingua/pdf/Glossing-Rules.pdf>), a standardized way of translation in linguistics that shows both the original language, the translated language, and a morpheme-by-morpheme correspondence between both languages.

(Non-standard morpheme abbreviations: col = collective; dua = dual)

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vyBœ Bævu wintertime 'It is wintertime,	kuxæ it is,	xaxa, and	ŋœ a	œ a	bu-ŋumæ sg-sailor	mæ-vud- prog-to sit
ŋæ on 'on the stern of the	bu-zuvu sg-stern of	ky the	æ the	bu-θærœθyvy, sg-boat	bu-kœxæ small,	sg-fishing pole
bu-zukœxæku, sg-hand in, 'in hand,	mæ-duvæb prog-to watch		a the	bu-paŋæ sg-sun	mæ-vudBœvu prog-to set	
θæŋœ kæxœ over	œ the	bu-bæxa sg-island	kæxœ. home.	œ the	ku-bæxa dua-island	home
mæ-Bapœ œ prog-to look snow	kyŋœ island	bæxa peaceful	vyθœ sg-fire	du-Byθæθyvy small	mæ-mæxu prog-to melt	the
Mæ-xykæ prog-to burn lies 'burning in front of houses,	xæku in	bæky front	ŋa of	du-kæxy, col-houses,	kœ as	du-pavœ col-fami-
mæ-θæθæ kyxæ prog-to cook sink	xœxu fish	kœmæ. to eat.		kœ as	bu-paŋæ sg-sun	mæ-xyxœ prog-to
a the 'the horizon,	vœky, horizon, he	bucœ is	xaxa prog-to turn	mæ-mykœ the	æ sg-boat	bu-θærœ

mæ-rœku ʃuv.py xae koebu œ Bœky xæbu
 pa the
 prog-to sail house to to prepare a meal delicious
 for œ
 ‘around and is sailing home to prepare a delicious meal for the’


bu-pavœ vyBœ xaxa xævy
 sg-family wintertime is calm
 ‘family. Wintertime is calm.

Conventions

1. ‘.’ when glossing signify a break in syllables
2. ‘(word)’ is the translated meaning of a word
3. /word/ is the phonetic transcription of a word
4. In CV(C)(C) syllable structure ‘C’ indicates a consonant, whilst ‘V’ indicates a vowel. ‘(C)’ indicates an optional consonant at the end of the syllable (a coda).

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