main()
{
    printf("Hello, World!");
}

Fall 2020

MURR
mountaineer undergraduate research review

Volume 5
THE MOUNTAINEER UNDERGRADUATE RESEARCH REVIEW

Volume 5, November 2020

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Cover Synopsis: Illustration by Kirsten Roys

My piece embodies the heart of undergraduate research – WVU goes first, leading research in many disciplines. The flowers, pistons, code, neurons, stars, and blue wave (flume) behind Woodburn are each related to research of friends I have made here at WVU. WVU undergraduate research exemplifies the idea of “Mountaineers go first,” and the variety of personally meaningful research-related objects in my art reflect that: each part of my drawing is something my friends and peers have worked on and advanced. It was a joy to be able to include pieces that each of my friends in research would be able to recognize and appreciate and say, “Hey, I did that! I learned something about that that no one else knew!” Even the blue wave of a flume relates to undergraduate research which a good friend has been working on for years. I drew what I felt was representative of undergraduate research and at the same time, personal, drawing from my experiences and making this art for those who complete this awesome research.
In this fifth volume of the Mountaineer Undergraduate Research Review, our students show the curiosity and creativity that drives all great discovery. Our University takes pride in helping undergraduates dig deeper and explore further while pursuing knowledge.

As one of just 115 Research 1 universities among the nation's more than 4,500 higher education institutions, we give our students hands-on research opportunities, as well as world-class mentors to guide them. In our nurturing environment, students follow their passions to great accomplishments.

The Mountaineer Undergraduate Research Review showcases these accomplishments while giving its staff an inside look at the academic publication process.

As a land-grant institution, West Virginia University's mission is improving lives. I am proud of our undergraduate scholars who are already pursuing discovery that will transform West Virginia and the world.

E. Gordon Gee
President, West Virginia University
Dear Mountaineers,

With the publication of this fifth edition of the Mountaineer Undergraduate Research Review, the Honors College is proud to see West Virginia University's vibrant undergraduate research community continue to grow and thrive.

Student research plays an integral part in many Mountaineers' journeys as they explore their academic passions and find the path to their future goals and dreams.

We at the Honors College know that through academic exploration and experimentation, we are all able to reach further and accomplish great things, not just for ourselves, but also for our community, our state, and the world.

The Honors College believes supporting research endeavors is paramount, and we enjoy working closely with the Office of Undergraduate Research to expand opportunities for all students at WVU to get involved. Honors is gratified to continue to see great research from students participating in programs such as the Summer Undergraduate Research Experience, and through student-led projects in the Honors Experiential and Community Engaged Learning Program.

The student researchers who have been involved in creating this volume have pushed themselves to learn about research in new ways, cultivating skills in journal article writing and editing, providing constructive feedback for their peers and learning more about the overall journal publication process. We’re proud of what you’ve accomplished here, and you should be too.

Keep researching. Keep learning.

Dr. Ken Blemings
Honors College Dean
The Office of Undergraduate Research (UGR) is enormously proud to support the student-led efforts that have resulted in this publication, namely the fifth volume of the Mountaineer Undergraduate Research Review (MURR). We are humbled by all the students, past and present, who have strived for this outcome.

It is easy to justify why it was important for UGR to devote significant time and resources to supporting our students in this endeavor. MURR, in particular, demonstrates to the public what our students can achieve when they are introduced to and engaged in WVU’s thriving research community. In addition, it reinforces WVU’s land-grant mission of “providing access and opportunity” and “advancing high-impact research.”

MURR was established in 2009 and was last published in 2014. Student-led from its inception, MURR was the brainchild of Molly Simis, then a junior biology and environmental geoscience double major within WVU’s Honors College. In 2016, UGR supported the Undergraduate Research Association student club in its efforts to revive MURR. These early efforts provided a base of materials on which the present effort was built. Eventually, UGR partnered with Jeffrey Petty and Zachary Gilpin, two students enrolled in the Honors Experiential and Community Engaged Learning (EXCEL) Program (est. 2019), to publish MURR as their EXCEL project. It is important to note that the students led MURR publication efforts. They determined MURR’s focus, timeline, and publication standards. They interviewed and approved volunteers, recruited reviewers and typeset journal articles. They worked together with UGR and EXCEL faculty and staff to foster institutional partnerships and mechanisms to enhance the sustainability of the journal.

Now in Fall 2020 and beyond, MURR will continue to advance opportunities for WVU students. It will provide an outlet for students to publish scholarly and creative works while deepening their engagement within their fields of study. In addition, it will allow students to experience the full editorial process from article submission, review and revision to formatting, proofreading, and publication. Through MURR, students will play an active and critical role in solidifying WVU’s reputation as an R1, very high research activity, institution. In turn, we would like to sincerely thank all the students, faculty, administrators, and departments that have contributed their support to this endeavor.

Sincerely,

Michelle Richards-Babb, Ph.D.
Director of the Office of Undergraduate Research and Professor of Chemistry

Kevin J. Walden, M.S.Ed.
Office of Undergraduate Research Program Coordinator and EXCEL Program Mentor
Development of Surrogate Hand for Impact Tests
Brison and Sosa detail the development of an anatomically and biomechanically accurate human hand to use for metacarpal glove safety testing.

The Gut Microbiome and Trimethylamine N-Oxide: Implications for Chronic Disease Risk and Dietary Regulation
Nevin reviews evidence for the “TMAO connection,” the molecular link between diet, the gut microbiome, and mechanisms of chronic disease.

Faculty Spotlights: Dr. Kate Staples and Dr. Cinthia Pacheco

Effects of Mouthrinses on Salivary pH After Acidic Drink Consumption
Fisher and colleagues examine the efficacy of several mouthrinses in buffering salivary pH to prevent dental erosion and inform dental professionals and patients alike.

Investigating the General Public's Perceptions of Bias in Forensic Science
Jurors’ perceptions of bias in forensic science is important to identify in pursuit of fair trials- Riley examines these perceptions and identifies potential paths forward in public education.

Student-Submitted Artwork

The Robert Lepper Mural Painting: a Hidden Gem in White Hall at West Virginia University
Caplinger utilizes a battery of art history and forensic techniques to investigate the origins of an impressive but often overlooked campus landmark.

Dundon analyzes the magnum opus of one of America's most accomplished playwrights and explores the ways in which he personifies himself in his work.

Swords, War, and Goldsmithing: Benvenuto Cellini and Masculinity in Sixteenth-Century Italy
Hogbin examines the autobiography of one of Renaissance Italy's most renowned artists and connects his portrayals of violence to concepts of masculinity during this time period.

Acknowledgements/From the Editors
Development of Surrogate Hand for Impact Tests

Trevor A. Brison, Eduardo M. Sosa

West Virginia University Department of Mechanical and Aerospace Engineering

Despite continuous advancements in technology and safety procedures, hand injuries are still a significant problem in many industries. Metacarpal gloves are often used by workers to protect their hands against impacts, cuts, and other hazards. Importantly, testing the level of impact protection offered by different designs of metacarpal gloves cannot be done with living subjects. This limitation requires the use of a surrogate hand which can be used consistently and systematically in controlled impact tests. This work focuses on the development of a surrogate hand which can be manufactured and used for this purpose. The surrogate hand developed in this work is comprised of a bone structure and a flexible synthetic gel material, and the hand design is based on digital models obtained through laser scanning of bone and hand shapes. These digital models were scaled and assembled using a mesh editing software to generate a representative hand with the required size and posture. The resulting hand model was materialized with a 3D-printed bone structure surrounded by synthetic gel with shape, proportions, and flexibility resembling that of an actual hand.

Introduction

Hand injuries are a significant and common ailment in many industries, and even with advancements in technology and safety procedures, physical tasks which can produce hand injuries still exist. For example, in the mining industry from 2000 to 2018, there were nearly 42,000 reported accidents involving the hands of miners. This number of incidents represents almost 20% of the total number of reported accidents. 76% of these accidents typically involved the fingers and thumb, while the remaining 24% involve other portions of the hand (not including the wrist). The most common preventive measure against such hand injuries are protective gloves—namely, metacarpal gloves—which are commonly used in different manufacturing and extractive industries. These gloves are designed to protect hands against lacerations and impacts, among other workplace hazards. At the time of this study, there were at least forty-five glove manufacturers operating in North America which produced a variety of industrial gloves.

Metacarpal gloves are usually comprised of a set of fabric layers with external reinforcements made of thermoplastic rubber (TPR), which are intended to provide impact protection. The TPR reinforcements are generally placed in segments located on top of the fingers, knuckles, and thumb, or the dorsal metacarpal region of the hand. Other models include thick pads placed over the top and bottom surfaces of the glove. Despite the variety of metacarpal glove designs and providers, one aspect of the protection which is vaguely or sparsely referenced is the performance of metacarpal gloves against an impact hazard.

Due to a lack of consistent evaluations, there is uncertainty concerning the protective qualities of existing metacarpal gloves. Considering that it is not possible to use live hands to assess the impact protection of metacarpal gloves, an anatomically accurate and mechanically similar surrogate hand is needed to further evaluate the dampening qualities of metacarpal gloves. We previously created such a surrogate hand and successfully used it for preliminary impact testing of selected metacarpal gloves. Here, we detail the methodology to create the surrogate hand used for those tests. The main objective of this methodology is to define a series of steps to create an anatomically accurate surrogate hand.
Figure 1. Components of digital and manufacturing phases.

which can be manufactured consistently and used for further evaluation of the impact resistance of metacarpal gloves. Achieving this objective required the development of a series of steps to create the different parts which comprise the surrogate hand. In addition, measures of the performance of the surrogate hands manufactured following the proposed methodology are included.

Methods

The surrogate hand developed in this work consists of two main components: the bone structure (comprised of phalanges, metacarpal and carpal bones) and a soft material representative of the soft hand tissues (without a specific distinction between skin, fat, muscles, tendons and ligaments). The development of the surrogate hand was completed in two main phases: a digital phase and a manufacturing phase (Figure 1).

Digital Phase – Bone Structure

The hand bone structure was created by laser-scanning the 27 bones of the human hand, which were provided by the WVU School of Medicine, Department of Pathology, Anatomy, and Laboratory Medicine (Figure 2A). A digital version of each bone was obtained using a laser scanner (NextEngine, Santa Monica, CA). The scanning process required fixing bones on a rotary platform in order for the laser scanner (Figure 2B) to capture multiple still images of the bones needed to create a three-dimensional digital model (“mesh”) of each bone (Figure 2C). These images were assembled following reference points marked on the bones.

After the 27 bone meshes were created, they were imported into CAD/CAM software (Fusion360, Autodesk, San Rafael, CA) for post-processing and assembly. The post-processing involved repairs for closing the mesh body and for smoothing the surfaces to eliminate gaps and inconsistencies. The repairs ensured that all nodes of the mesh were connected correctly and formed a “watertight” bone file. The individual bones were then assembled to generate a digital version of a hand in a relaxed, opened palm position. The entire bone assembly (Figure 2E) was scaled to fit the dimension of an average-sized human hand. Measurements on X-rays (Figure 2D) and existing skeletal hand models were used to validate the anatomical accuracy of the digital assembly. The carpal region of the bone assembly was then fused to the contact region except for the trapezium carpal bone to allow subsequent articulation of the thumb. The post-processing also included the addition of medullary cavities to the metacarpals and phalanges. The dimensions of these cavities was determined based on previous observations7,8 (Figure 2D). Additional minor
additions were implemented to simplify the fabrication process by creating a streamlined radius and ulna, breakaway bone joints, and pinholes to fix the bones in a mold.

**Digital Phase – Soft Tissue**

The creation of a hand model compatible with the developed bone structure involved selecting and acquiring a commercially-available digital hand model with accurate anatomical features in a relatively flat position and suitable for subsequent fabrication of testing prototypes. A hand model created by Ubersculpts (CGTrader 3D Modeling, New York, NY) was selected due to its high mesh density, anatomical accuracy, multiple hand orientation options, and scalability (Figure 3A–C). This model needed minor modifications to fit the bone assembly and small adjustments to fit average human hand dimensions\(^9\)–\(^11\). The flat hand position was selected to match the configuration of the experimental setup used for preliminary impact tests reported previously\(^6\). The final step for the creation of the digital hand consisted of merging the bone assembly with the soft tissue portion to create the full digital hand model. The position of the bones in the resulting hand was re-verified against X-ray images of actual hands to ensure proper fitting within the hand volume.

**Digital Phase – Hand Mold**

The mold for manufacturing the surrogate hands was developed based on the requirements of being scalable and 3D-printable. To construct the mold, Fusion360 software was used to generate a rectangular prism and a negative cavity within the prism. This prism was divided into two parts by a reference plane which split the mold body into two separate parts. The position of the reference plane was carefully selected to allow for easy cast removal from the mold without distorting the organic shape of the hand. Each of the mold halves included leader pins and slots to guide and join the halves when pouring the cast materials. The mold halves also included smaller pins to support and maintain the bone structure during casting (Figure 3D–F). The locations of the pins alternated between the top and bottom of each articulate bone section to prevent any movement during the casting process. The pouring sequence was designed to minimize the formation of air pockets within the cavity, such that any bubbles formed during casting could be removed with light percussive assistance. The product was a two-part mold which can hold the bone structure in place while casting molten gel material (Figure 3F).

**Manufacturing Phase – Material Selection**

The digital models described previously were materialized by a combination of 3D printing of the bone structure and casting of medical-grade synthetic gel for the soft tissues in a 3D-printed two-part mold derived from the digital hand models. The decision to use
medical-grade synthetic gel to represent the soft tissues of the hand drove the selection of 3D printing materials for the bone assembly and the mold. Two grades of synthetic gel were used for this work: gels #0 and #4, (Humimic Medical, Greenville, SC). The melting temperatures of these two gel types ranged from 116°C to 121°C, which constrained the selection of 3D printing materials for the bone assembly and mold.

The chief requirement of the 3D printing material for the bone assembly was a strength and density similar to that of human bones\textsuperscript{13}. Additionally, the melting temperature of the bone material must have been higher than the melting temperature of the gel used to represent the soft tissues. Several material candidates were considered for the bone structure. A nylon filament (PA6, Nylstrong by Smartfil, Spain) was ultimately selected for its mechanical and thermal properties (melting temperature in the range of 245°C to 265°C).

**Manufacturing Phase – Bone Structure**

The technique selected for 3D printing of the bones and the mold was Fused Filament Fabrication (FFF), an additive manufacturing process which uses thermoplastic and thermostet filaments to create 3D objects. The digital bone structure described previously was converted to a 3D-printable file in a .gcode format (LulzBot TAZ Pro, Aleph Objects, Loveland, CO) (Figure 4A). In order to allow for a smoother transition during manufacturing, additional geometric components were added to facilitate the articulation of the bones with breakaway supports to maintain the bone orientation and reduce printer support clean up. After completion of the 3D printing process, the finger joints were coated with a silicon material to mimic ligaments, and the support material was removed to obtain the fully assembled bone structure (Figure 4C).

**Manufacturing Phase – Two-Part Mold**

The two-part mold was manufactured using the same FFF technique used for the bones. The two halves of the mold were printed separately. The synthetic gel melting temperature also drove the selection of the 3D printing material used for the mold. Several material candidates were considered, and ultimately polylactic acid (PLA) was selected. PLA has a melting temperature in the range of 130°C to 180°C, which ensured that the mold would not be distorted or damaged during gel casting. Two molds were manufactured: one for the specimens cast with gel # 0 and one for the specimens cast with gel #4 (Figure 5A–B).

**Manufacturing Phase – Full Hand**

After 3D printing the two-part mold, each of the halves was coated with a demolding agent to allow for easy removal of the finished product. Once the bone joints were cured, the bone hand was arranged in the mold, relying on the pins and pinholes to place and maintain the bone position within the hand cavity created by the two-part mold. A compressible silicon gasket was then placed between the mold halves before clamping them together,
leaving the mold ready for the gel casting (Figure 5A). The synthetic gel was heated to 120°C until it liquified and then poured into the mold while the mold was tilted to allow smooth flow of material to each finger, as well as to facilitate the removal of air out of the hand cavity. After fully pouring the molten gel, percussive assistance was applied to complete the degassing of the gel as it cooled down. The resulting cast was left to cool down and cure for 24 hours before demolding. An identical procedure was applied for creating hands with gel #0 and gel #4 (Figure 5B–C).

Results and Discussion

The procedure described in the previous section was implemented to initially manufacture five hand specimens using gel #0 and five specimens using gel #4. The specimens were weighed and measured to verify dimensional stability. For gel #0, the average weight was 462g (SD = 10g) and a coefficient of variation (COV = SD/average) of 2.3%. For gel #4, the average weight was 415g (SD = 8g), COV = 1.9%. The difference in weight between specimens with different gels is due to the difference in densities: 880.38 kg/m³, and 834.34 kg/m³, for gel #0 and gel #4, respectively. Moreover, the total lengths of the specimen and widths of the palm were also measured, and all specimens showed a COV of <1.0%. These results confirm that the molds did not distort during gel pouring and maintained their original shape through multiple casts, thus maintaining dimensional stability.

The use of two types of medical-grade synthetic gel changed the overall stiffness of the resulting surrogate hand. A measure of the gel stiffness while in a solid state is known as the hardness of the gel. The Shore hardness scale is typically used for soft materials. In this scale, higher numbers on the scale indicate a higher resistance to indentation and thus a harder material. In contrast, lower numbers mean less indentation resistance and typically correspond to softer materials. Gel #0 and gel #4 had reported average Shore ratings of 21.4 and 3.3, respectively. The hardness of each gel type controlled the overall flexibility of the hand. Notably, specimens manufactured with gel #4 displayed a flexibility closer to the flexibility of an actual hand.

The bone structure maintained its shape and position within the hand during the casting process, confirming the suitability of holding pins and pinholes to support the bones. One aspect observed in the specimens (using both gel types) was the bonding between the gel and bones: bonding at the fingers and fingertips appeared generally weaker than bonding at the knuckles and metacarpals. Importantly, this difference in bonding could affect overall hand model behavior during impact tests. In the future, addition of a bonding agent to the surface of the bones before pouring the gel may improve the
adhesion between these materials.

Specimens were also subjected to controlled impacts to determine the range of impact reaction forces for unprotected hands following the procedure described previously\(^6\). Impacts were performed on interphalangeal (PIP) joints, metacarpophalangeal (MCP) joints, and at the midpoint of the metacarpal bones (MET). At each position for gel #0, the average impact reaction forces and standard deviation (SD) were 2856N (599N), 2193N (684N), and 1468N (634N), respectively. A set of preliminary impact tests were also performed on the specimens manufactured with gel #4. For these specimens, the average impact reaction forces and standard deviations were 2571N (104N), 1890N (125N), and 1325N (158N), respectively. Importantly, these values are in the range of 75% of the values reported in published literature for experiments performed with cadaveric hands (3835N for PIP joints and 2740N for MCP joints)\(^4\). In order to reduce this gap, further adjustments will be necessary for the 3D printing settings of the bone structure, to increase the strength of the surrogate bones and reduce the variability in the impact reaction forces seen in the specimens manufactured with gel #0.

**Conclusions**

A methodology for creating a surrogate hand which can be manufactured using 3D printing and gel casting techniques was presented. The physical models developed in this work can be quickly and readily reproduced using additive manufacturing for the bone structure and synthetic gel casts in a two-part mold for the soft tissue. The resulting surrogate hands were able to maintain dimensional stability after casting. With adjustments in the 3D printing settings of the bone structure, these surrogate hands can help further validate research on the impact-protective qualities of various metacarpal gloves. Furthermore, the techniques developed in this work can be refined to ensure consistent manufacturing, as well as expanded to other body parts to obtain valid and accurate substitutes for testing other protective systems. The digital models developed in this work also provide the basis for developing computational simulations and parametric studies for further evaluation of forces and damage resulting from an impact on the hand.

**Acknowledgments**

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Competing Interests

The authors declare no competing interests.

References


About the Author:

Trevor Brison is a Morgantown native studying mechanical engineering at the Statler College of Engineering and Mineral Resources. His fields of interest include biomedical science (specifically biomimicry and prosthesis), robotics, and material science. After graduating, Trevor intends to continue his education in specialized work environments or graduate school. In his free time, he explores other interests including food chemistry, specifically in fermentation, and chemicals which affect taste receptors.

How to Cite This Article:

The leading causes of death in the United States include many chronic diseases with modifiable risk factors including ischemic heart diseases. Gut microbiota-dependent trimethylamine N-oxide (TMAO) synthesis has been implicated in cardiovascular disease risk in recent years. New evidence may also implicate TMAO involvement in other chronic diseases including diabetes mellitus and chronic kidney disease. The role of diet in TMAO synthesis has also been of considerable interest, as certain dietary precursors are known to modulate circulating TMAO. The gut microbiome is indeed susceptible to diet-induced change which may modulate the risk for chronic disease. Plant-based diets are considered by many to be beneficial for gut health and may play a protective role by reducing TMAO synthesis. This review discusses the purported role of TMAO and the mechanisms by which TMAO may contribute to atherosclerosis and chronic disease risk. The role of diet in chronic disease is also discussed with emphasis on utilizing clinical nutrition to reduce the burden of disease.

Introduction

The leading causes of death in the United States include ischemic heart diseases, diabetes mellitus and chronic kidney disease (CKD), among others. While these chronic diseases are multifactorial, the development of many diseases and the risk for all-cause mortality are derived in part from lifestyle factors including diet. Considerable attention has recently been given to the role of gut microbiota in chronic disease, as well as how diet modulates the human enterotype. Over the last decade, research on mechanisms of chronic disease have revealed an obligate role for gut microbiota in production of pro-atherogenic species including trimethylamine N-oxide (TMAO). TMAO is produced after phosphatidylcholine and related metabolites are converted by host microbiota to trimethylamine, which undergoes further oxidation in the liver by flavin monooxygenase enzymes (FMOs). This article reviews the proposed mechanisms by which TMAO may contribute to atherosclerosis and chronic disease risk. Special attention is given to the role of diet in modulating the human enterotype as well as the therapeutic viability of dietary regulation in modifying chronic disease risk.

TMAO Synthesis

A study published in 2011 by Wang et al. identified a molecular pathway by which phosphatidylcholine is converted to choline and metabolized by gut microbiota to trimethylamine (TMA). After absorption of TMA into host circulation, hepatic enzymes further oxidize this species, producing TMAO. Specifically, flavin monooxygenase 3 (FMO3) carries out this oxidation and displays the greatest specificity towards TMA. Further characterization of this purported mechanism has revealed that other phosphatidylcholine-related species such as L–carnitine and betaine also result in the production of TMAO via conversion to TMA as an intermediate. This mechanism of TMA production has recently been revised for L–carnitine, as the intermediate gamma–butyrobetaine (GBB) is generated before conversion to TMA in humans.

Elucidating the interplay between diet and TMAO synthesis is important, as plasma TMAO levels are associated with cardiovascular
disease (CVD) risk and mortality in a dose–dependent manner\textsuperscript{14}. Observational studies have also revealed that TMAO levels are predictive of major adverse cardiac events (MACEs) in certain population cohorts; specifically, Li et al. found that, in patients presenting to the emergency department with symptoms of chest pain, plasma TMAO levels were independently predictive of future MACEs\textsuperscript{15}. Diet and the human enterotype are intrinsically linked to TMAO synthesis, as choline–containing species are converted to TMAO by gut microbiota\textsuperscript{9,11}. Furthermore, animal products are largely implicated in TMAO production, as both choline and L–carnitine are concentrated in foods such as meat, dairy and eggs\textsuperscript{9,16}. Interestingly, the choline derivative betaine is found more largely concentrated in plant foods and is associated with CVD risk when there is a concomitant rise in TMAO levels\textsuperscript{17,18}.

**TMAO Mechanism of Action in Atherosclerosis**

Rather than serving as a biomarker for a diet high in saturated fat and cholesterol, TMAO has been characterized in many studies as an contributor to atherosclerosis. These studies have implicated TMAO in lipid metabolism dysfunction and inhibition of reverse cholesterol transport (RCT) as well as multiple inflammatory mechanisms\textsuperscript{19}.

Wang et al. discovered that dietary supplementation of phosphatidylcholine–derived metabolites to atherosclerosis–prone mice resulted in increased expression of the macrophage scavenger receptors CD36 and SR–A19. These macrophage–specific receptors then facilitate creation of foam cells—macrophages which engulf oxidized low density lipoprotein (LDL) and contribute to the formation of atherosclerotic plaques\textsuperscript{9,20}. Importantly, high levels of dietary choline induced macrophage foam cell formation in a microbiota–dependent fashion, as mice treated with broad spectrum antibiotics show complete mediation of this phenotype\textsuperscript{9}. Additionally, TMAO has also been found to increase risk of thrombosis and modulate platelet hyperreactivity in mouse models\textsuperscript{21}.

Experimental data suggests that the capacity of gut microbiota to generate TMAO is important in atherosclerosis progression\textsuperscript{9,22}. A study published by Gregory et al. demonstrated that mice receiving large–intestine microbial transplants from atherosclerosis–prone donor mice had increased incidence of atherosclerosis compared to those receiving microbial transplants from atherosclerosis–resistant mice\textsuperscript{22}. Recently, a CD36–dependent pathway has been identified whereby TMAO stimulates macrophage migration and foam cell formation. SiRNA–mediated knockdown of the cell–surface receptor CD36 subsequently downregulated these processes and inhibited foam cell formation. The action of enzymes including MAPK (mitogen activated protein kinase) and JNK (jun N–terminal kinase) in a downstream signaling pathway were also shown to be necessary for foam cell formation\textsuperscript{23}. Several other pathways of inflammation and immune responses to TMAO have also been explored, including activation of atherosclerosis–promoting proteins by nuclear factor–κB\textsuperscript{19,24}.

Studies suggest that TMAO also modulates gene expression of certain cholesterol transporters and other enzymes regulating bile synthesis in mice, leading to a reduction in the total bile acid pool and inhibition of reverse cholesterol transport (RCT)\textsuperscript{10,19,25}. Koeth et al. found that cholesterol transporter expression was reduced in enterocytes after dietary TMAO supplementation. Furthermore, dietary TMAO supplementation altered gene expression (mRNA levels) of cholesterol transporters in enterocytes, hepatocytes and macrophages\textsuperscript{10}. These findings reveal how TMAO might affect cholesterol elimination at multiple levels, as well as how TMAO can lead to inhibition of RCT\textsuperscript{10}. Interestingly, FMO3 also plays an important and independent role in lipid metabolism, as targeted knockdown of FMO3 results in increased non–biliary macrophage RCT and restoration of cholesterol equilibrium\textsuperscript{26}. Taken together, these results suggest that TMAO may increase cholesterol deposition in peripheral tissues due to
decreased elimination and RCT, resulting in injury to the arterial endothelium and atherosclerotic plaque formation. Uregulation of macrophage scavenger receptor expression may increase engulfment of LDL cholesterol and foam cell formation, further exacerbating this process.

Surprisingly, one study in mice found that TMAO slowed aortic lesion development. Collins et al. purport that TMAO may actually have a protective effect on arterial function, preventing atherosclerosis. Additionally, one review questioned the role of TMAO as a deleterious molecule, as TMAO is used as an osmolyte in marine animals, and fish (TMAO-producing) consumption is associated with health benefits. Observational studies have also found considerable intra-individual differences in TMAO levels independent of diet. While these findings seem to challenge the best available balance of evidence, the role of TMAO in atherosclerosis may need further clarification.

**TMAO in Other Chronic Diseases**

Recent evidence has implicated TMAO in other chronic disease processes. In 2006, Bain et al. discovered TMA and TMAO accumulation in the blood of patients with end-stage renal disease prior to hemodialysis treatment. While TMA and TMAO normalized to healthy levels following dialysis, their accumulation continued before subsequent treatment. Years later, a cohort with chronic kidney disease (CKD) was found to have elevated TMAO levels in blood plasma independently associated with increased risk for MACEs. Further studies found increased TMAO-associated risk for all-cause mortality in those with CKD, as TMAO has been identified as an independent predictor of systemic inflammation and mortality in these patients. Another study showed that TMAO levels are also inversely correlated with glomerular filtration rate (GFR), an indicator of kidney function. While these results suggest a causal relationship between TMAO and kidney function, interpretation is complicated by renal clearance of TMAO. Elevated TMAO in patients with CKD may simply result from pre-existing kidney dysfunction and subsequent TMAO retention. On the contrary, some animal studies suggest TMAO may promote renal fibrosis and vascular calcification. Recent studies in rats identified TMAO-associated vascular calcification via the NLRP3 and nuclear factor-κB signaling pathways, but further investigation in humans is warranted.

A number of recent studies have also identified a causal relationship between TMAO and type-2 diabetes (T2D). Li et al. showed that increases in phosphatidylcholine consumption were associated with greater risk of T2D in three large prospective cohorts. Further studies reported up to 10-fold increases in blood plasma TMAO levels in diabetic mice compared to wild-type littermate controls. Additionally, these mice displayed an increased body mass index (BMI), and TMAO levels increased with age in both diabetic mice and controls. This study also identified a trend between TMAO levels and diabetes status in human patients: individuals with prediabetes had higher TMAO levels than those with normal glucose tolerance, and those with frank T2D had the highest circulating TMAO, though this data was not statistically significant.

Subsequent research in younger cohorts has found no association between TMAO levels and increased T2D risk, and only a modest increase in prediabetes prevalence in a non-linear fashion for men and women 20–55 years old. These results may suggest that a decline in renal function is key to linking TMAO and conditions including T2D. As T2D is a risk factor for kidney disease, progressive renal dysfunction may reduce TMAO clearance and signal adverse metabolic events already underway. Associations between increasing age and TMAO levels may support this conclusion, as declining kidney function and increased insulin resistance may happen independently of TMAO action. General gut dysbiosis is indeed implicated in T2D, but the role of TMAO as an effector of these processes is not currently evident. While the role of TMAO in atherosclerosis and CVD is better characterized, further interventional studies
are needed to characterize a potential causal relationship between TMAO and other chronic diseases.

**Diet and TMAO Synthesis**

Diet plays an important role in TMA/TMAO production, as the precursors for TMA synthesis are derived from food\(^9,10\). Both choline and L-carnitine are concentrated in animal products; however, the contribution of these foods to chronic disease risk through TMAO production has remained controversial.

Koeth et al. first identified a decreased capacity for vegans and vegetarians to generate TMAO in their 2013 study\(^9\). Postprandial ("post-meal") TMAO production after an L-carnitine supplement was significantly reduced for both vegans and vegetarians when compared to omnivores. Fasting TMAO levels were also lower in this cohort. One subject who followed a vegan diet for more than five years undertook an L-carnitine challenge and had almost no capacity to generate TMAO as well as nominal fasting plasma and urine TMAO levels\(^10\). Recent evidence suggests this phenomenon may be due to diet-dependent conversion of the intermediate GBB to TMA\(^11\). This study identified that both omnivores and vegans/vegetarians rapidly convert L-carnitine to GBB, but omnivores have a much greater capacity to subsequently metabolize GBB to TMA. These results suggest that omnivores and vegans cultivate enterotypes with varying capacities to metabolize GBB to TMA. Wu et al. independently reported similar results: after an oral carnitine challenge test (OCCT), omnivores had a much greater capacity to generate TMAO than the vegetarian subjects in the study\(^41\). Interestingly, some long-term vegetarians still demonstrated a remarkable ability to generate TMAO after the OCCT, which may be due to continued consumption of eggs and dairy\(^41\).

Recently, diet-dependent taxonomic shifts in microbiome composition have been investigated for those on plant-based versus animal product-based diets\(^7\). David et al. found that switching between plant-based and animal product-based diets can rapidly alter the gut microbiome in as little as one day. One vegetarian subject in the study transitioned from a *Prevotella*-rich microbiome to a predominantly *Bacteroides*-rich microbiome after just four days on an animal product-based diet\(^7\). Interestingly, a *Prevotella*-rich microbiome has been associated with increased synthesis of short-chain fatty acids (SCFA) implicated in suppression of inflammation and cancer\(^62\). A *Prevotella*-rich gut microbiome across vegetarians and vegans has indeed been corroborated by other studies and may stem from a higher intake of dietary fiber\(^43,44\).

Many researchers have investigated the effects of Mediterranean diets (MDs) on TMAO synthesis, as MDs are often associated with reduced risk for chronic disease\(^45\). Some studies suggest MDs may lower TMAO production, but results have varied. Griffin et al. found that a 6-month MD intervention did not significantly alter plasma TMAO levels in a cohort of healthy adult males\(^46\). Other studies have also suggested this dietary intervention may not significantly alter fasting TMAO levels, but that postprandial TMAO levels may be more sensitive to dietary intake. Conversely, one study showed that MDs lower TMAO levels when compared to a high-fat Atkins diet, but both were outperformed by an Ornish-style plant-based diet\(^47\). Indeed, a landmark 1990 study by Ornish et al. showed that a plant-based diet and other healthy lifestyle behaviors were sufficient to reverse atherosclerotic lesion size in those with coronary artery disease\(^48\). The efficacy of a MD could depend on the relative consumption of fruits, vegetables and plant foods to animal products implicated in TMAO production.

Together, these studies may suggest that a low-fat, plant-based diet provides the best therapeutic dietary intervention to reduce TMAO production. Indeed, patients suffering from trimethylaminuria (caused by mutations in FMO3 which disrupt TMA metabolism\(^49,50\) often become vegans to reduce circulating TMA and find relief from the disorder\(^9\). Utilization of a plant-based diet to modulate the gut enterotype and reduce TMAO production may be the safest and most cost-effective therapy.
currently available to patients with elevated TMAO and at risk for CVD and other cardiometabolic disorders. It is currently unclear how veganism and ovo–lacto-vegetarianism compare to one another as effective therapies, but a more strict plant-based diet may be preferable, as choline is concentrated in eggs and other dairy products\(^\text{41,47}\). While choline is an essential nutrient for human health, some plant sources high in dietary choline have not been shown to exert the same deleterious effect seen from choline-rich animal products. This may stem from their effects on the liver enzyme FMO3, as the choline-rich brussel sprouts were shown to downregulate FMO3 activity and TMAO production\(^\text{51}\). One study also found that choline-rich pistachios lowered TMAO levels for those on pistachio-supplemented diets\(^\text{52}\). An Ornish–style plant-based diet was also found to increase plasma betaine levels, but the association between betaine and CVR risk was lost without a concomitant rise in TMAO\(^\text{47}\). On the contrary, one study showed a diet high in resistant starch elevated TMAO levels in the short term\(^\text{53}\).

**Conclusion**

Taken together, diet-dependent conversion of phosphatidylcholine-related metabolites to TMAO is largely implicated in atherosclerosis and the progression of cardiovascular disease. TMAO is purported to exert a deleterious effect on the arterial endothelium via increased foam cell formation, inhibited reverse cholesterol transport and promotion of systemic inflammation. Clarification of the exact role of TMAO in these processes as well as investigation of the causal relationship between TMAO and chronic diseases like CKD and T2D are warranted. Limiting the consumption of animal products rich in choline and L-carnitine while transitioning to a plant-based diet may be the safest and most cost-effective dietary intervention currently available to those with elevated TMAO levels. Further randomized controlled trials are needed to elucidate the long-term impact of a plant-based diet on gut health and one’s capacity to produce TMAO.

**Competing Interests**

The author declares no competing interests.

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How to Cite This Article:

Kate Kelsey Staples, PhD
Associate Professor and Chair: History Department

Research is crucial for undergraduate students at WVU in order to develop and hone their critical and analytical thinking skills which they will wield in their professional, public, and personal lives moving forward. The Mountaineer Undergraduate Research Review presents WVU students with the opportunity to take the research process a step further by allowing them to publish their writing. This opportunity allows students to reflect carefully on their written work, reexamining their arguments and evidence, which embodies a process that makes all scholars better researchers and communicators. I’m honored to be a part of the development of undergraduate scholarship at WVU!

Cinthia Pacheco, PhD
Assistant Director: WVU Office of Undergraduate Research

Undergraduate Research is an active and essential part of WVU. As an R1 Institution, the University is always seeking excellence in research. Involving students in research activities, as early as their freshman year, has shown enormous benefits toward this end. Undergraduate research enables students to develop independent critical thinking and to improve their problem solving and communication skills. Additionally, students that participate in research tend to establish better connections with their faculties and have higher rate of persistence in their majors.

I started research during my second year of college, which opened an array of different opportunities that I had never envisioned before. As an undergraduate researcher, I had the privilege to write my first research article, which was published in a peer reviewed journal. At that time I wasn’t fully aware of the benefits this experience would give me. However, when I compared myself to my peers who did not have that same experience, it was clear to me how much easier I would give presentations, write abstracts, research papers for publication, and fill out applications for graduate schools. Undoubtedly, performing research and writing a research article is a good way to improve written communication skills!
Effects of Mouthrinses on Salivary pH After Acidic Drink Consumption

Megan S. Fisher, Matthew Duggan, Yilin Cai
West Virginia University School of Dentistry

Consumption of acidic beverages is a frequent occurrence for many dental patients causing an increase in the acidity of the oral environment and potentially contributing to dental erosion. Currently, no recommendations are available for a protocol to prevent such an acidic environment if one chooses to consume acidic beverages. The purpose this study was to examine five common mouthrinses for their efficacy in buffering salivary pH after acidic exposure, as measured from a group of subjects at various time intervals after Coca-Cola® consumption. All mouthrinses increased salivary pH to more basic levels than without a rinse. Mean salivary pH testing indicates that Cool Mint Listerine® elevated salivary pH the fastest. At 20 minutes post-rinse, only distilled water and ACT® Anticavity mouthrinses resulted in more basic salivary pH values than baseline. However, the only mouthrinse which produced statistically significant salivary pH buffering was ACT® Anticavity. The results of this study increase dental professionals’ awareness of buffering efficacies of the tested mouthrinses. Further evaluation of ACT® Anticavity mouthrinse in future studies would arrive at a definitive solution for patient recommendation.

Introduction

Many dental patients report frequent acidic beverage consumption; increasing prevalence has made such consumption an oral health concern to both dental professionals and patients. Healthy pH of the oral cavity ranges between 6.7 and 7.4, yet many popular beverages have a much lower pH. Concern arises when the acidity of the oral environment reaches the critical threshold of enamel erosion at pH 5.5. Importantly, recent studies have found that the consumption of acidic beverages can lower oral pH below this critical threshold. Substantial research on oral pH reduction after drinking acidic beverages suggests that pH drop is most significant immediately after consumption, and that pH returns to pre-exposure levels within a half-hour. The use of medicaments pre and post-exposure for a more efficient neutralization of salivary pH and enamel protection have been reviewed in previous research studies. Literature from Turissi et al. noted that a combination of calcium lactate pre-rinse followed by a sodium fluoride rinse protected enamel surfaces from citric acid erosion as opposed to sodium fluoride alone. Other analyses by Lindquist et al. incorporated the use of post-drink mouthrinses and other products to investigate their effectiveness in accelerating the return of salivary pH to acceptable levels. Researchers have noted the pH-buffering abilities of neutralizing agents including antacid tablets, chewing gum, mineral water, milk, and water. More specifically, research evaluating post-exposure rinsing with Listerine® Antiseptic and Periobacter® chlorhexidine mouthrinses showed that it requires 15 minutes for pH to return to pre-exposure levels following acidic challenge. Research evaluating CariFree CTx4® rinse—a product marketed for pH neutralization—concluded that chlorhexidine is still the preferred antibacterial rinse for inhibiting the bacteria Streptococcus mutans and Lactobacillus acidophilus. To date, there have been no studies comparing the efficacy of multiple salivary pH-altering mouthrinses against one another and against a rinse of distilled water. The purpose
of this research study is to evaluate accessible options for returning salivary pH to a healthy level after acidic exposure. Results from this study may be beneficial in providing dental professionals with information regarding acidic beverage consumption.

Overall, this research supports the hypothesis that post-exposure mouthrinses can buffer salivary pH quicker than distilled water or lack of post-exposure rinse. In addition, this study provides dental professionals with insight about the effects which the tested mouthrinses can have on a patient’s salivary pH post-acidic exposure. This study also provides necessary statistics and details for advancing this area of research to build a basis for future patient education on this topic.

Methods

Experiments were conducted on twenty participants at West Virginia University (WVU). For each participant, salivary pH was measured initially, immediately following consumption of Coca-Cola, and at several timepoints after rinsing with commonly recommended dental mouthrinses. This study specifically focused on Coca-Cola as the acidic beverage, as it is the most accessible brand of beverages available on-campus at WVU. According to a recent study, Coca-Cola has a pH of 2.37, an acidity considered “extremely erosive”.

Study participants were all students in the 2019/2020 West Virginia University junior dental hygiene class and consisted of 19 females and 1 male. Participants’ WVU Axium dental records were screened to ensure that participants were free from tooth decay and possessed no systemic diseases which would inhibit their participation. Participants were asked about their current consumption of acidic beverages to be sure that exposure to acidic erosion during the study was not outside of each participant’s normal consumption. Researchers selected participants using a non-probability sampling.

This group had a narrow range of ages (20–29 years) and came from various backgrounds; however, all participants had the same level of dental education. The participants played an active role in recording their own salivary pH levels, but recordings were verified and monitored by research investigators to resolve recording-based questions. Each participant, during the course of his/her studies as a dental hygiene student, was educated in the proper reading of pH test strips. No participants reported issues with color blindness.

All research procedures on human subjects were evaluated and approved by the Institutional Review Board (IRB) of West Virginia University (protocol# 1903485364). At the time of enrollment, all study participants were presented with informed consent forms which documented the study, purpose, procedures, risks, and possible research outcomes regarding participation in the study.

During the course of the study, the participants gathered on six separate occasions with at least 8 hours in between testing (to allow for a washout period). Participants were directed to abstain from food or drink for 20–minutes prior to testing. At time of testing, participants first recorded their baseline salivary pH, consumed 50mL of Coca-Cola within 30 seconds, and subsequently recorded salivary pH at 1-minute, 10-minutes, and 20–minutes post consumption. The research instructions informed participants to drink without a straw and without swishing. The study had a crossover design such that all participants used each of the mouthrinses on separate days (Table 1).

Mouthrinses included in this study were Cool Mint Listerine®, CariFree CTx4®, chlorhexidine, ACT® Anticavity, and distilled water. Wilcoxon rank sum analysis was used to

<table>
<thead>
<tr>
<th>Day</th>
<th>Test salivary pH on each participant</th>
<th>Drink 50mL Coca-Cola®</th>
<th>Test salivary pH at 1-minute, 10-minutes, and 20–minutes.</th>
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<td>1</td>
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<td>Drink 50mL Coca-Cola®</td>
<td>Test salivary pH at 1-minute, 10-minutes, and 20–minutes.</td>
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<td>Test salivary pH on each participant</td>
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<tr>
<td>3</td>
<td>Repeat Day 2 protocol with Rinse B (ACT® Anticavity)</td>
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<td>4</td>
<td>Repeat Day 2 protocol with Rinse C (Cool Mint Listerine®)</td>
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<td>5</td>
<td>Repeat Day 2 protocol with Rinse D (Chlorhexidine)</td>
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<tr>
<td>6</td>
<td>Repeat Day 2 protocol with Rinse E (CariFree CTx4)</td>
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Table 1. Summary of testing procedures.
compare mean salivary pH levels at each time increment for each mouthrinse against all independent variables (i.e., each rinse in Table 1). A p-value of less than 0.05 was considered statistically significant.

Results

Our results show that salivary pH generally increased faster and to a more basic reading with a mouthrinse than without (Figures 1 and 2), consistent with previous results and claims by mouthrinse providers.

Figure 1 depicts temporal change in pH adjusted to baseline following acidic exposure and post-exposure rinse with each of six treatments. Figure 2 depicts these results with the addition of error bars to visualize standard deviation (SD). It is important to note that Cool Mint Listerine demonstrated the most dramatic initial pH elevation following acidic consumption. Interestingly, CariFree CTx4, the mouthrinse with the most basic documented pH (10.5), did not elevate pH to the level that Cool Mint Listerine did at 1-minute post rinsing, nor did it perform as well as other mouthrinses at later measurement times. At 20-minutes post rinse, the only rinses with salivary pH significantly more basic than without a mouthrinse were ACT Anticavity and distilled water (Figure 2).

The heat map in Figure 3 shows significance levels of pairwise pH differences among the 6 rinse treatments at the indicated timepoints. Significant results (p<0.05) are colored dark red. At the 1- and 10-minute post rinse testing marks, both Cool Mint Listerine and ACT Anticavity showed significant differences from the majority of rinse treatments. Importantly, the only intervention with a significant p-value at 20-minutes post rinse was ACT Anticavity.

Discussion

Dental patients often disclose their acidic beverage consumption to dental professionals; however, besides total avoidance of acidic beverages, few recommendations on decreasing erosion risk are available to patients. Overall, this study was designed to examine five different mouthrinses for their efficacy in returning salivary pH to a healthy level after acidic exposure. To begin examining this question, a clinical study was performed with consenting participants at the West Virginia University Department of Dental Hygiene. The current study stands in contrast to previous studies of salivary pH and acidic

![Image](image_url)

Figure 1. Temporal salivary pH changes after acidic beverage consumption among 6 post-exposure rinse treatments. Each point represents average value across study participants (n = 20)
beverage consumption, which involved pH measurements using a removable appliance. Such appliances are not expected to accurately reflect changes in salivary flow in an effort to return pH to baseline levels and decrease enamel erosion\(^4\).

Overall, our results show that there are post-exposure mouthrinses available to patients for significantly elevating their salivary pH after acidic beverage exposure. Based on the results of this study, using any of the tested rinses after an acidic beverage should increase salivary pH more than without a post-exposure mouthrinse.

At 20 minutes post-rinse, only two rinses (distilled water and ACT Anticavity) returned salivary pH readings to baseline levels. Additionally, results showed that a Cool Mint Listerine rinse resulted in the most basic salivary pH initially after acidic exposure. Overall, the only rinse which showed a significant intervention effect was ACT Anticavity.

Interestingly, participants consistently experienced an increase in salivary pH in the minute after drinking Coca-Cola. These results are contrary to previous studies, which find that pH levels generally decrease within the first minute after acidic exposure\(^1,2\). The pH increase in this study is thought to reflect an increase in saliva production activated by the beverage. Indeed, salivary flow following acidic beverage consumption was measured in previous studies, and was often found to increase initially\(^1,6\).

The findings from this study have limitations in application to other acidic beverages and participant age groups. Other studies have examined multiple acidic beverages, but none have covered as many protective mouthrinses for pH elevation as this study\(^1,2\). Additional recommendations for further studies include the use of an electronic pH-meter to remove the need for calibration between different subjects and investigators. Broadening the number and age demographic of participants to analyze correlation between salivary pH levels and specific age groups would also give additional useful information. Finally, future studies could test other acidic beverages with the same mouthrinses to compare their relative efficacies after different acidic exposures.

This research provides evidence for dental professionals that post acidic exposure mouthrinses, especially ACT Anticavity, can
return salivary pH to baseline or a more neutral pH quicker than distilled water or no mouthrinse at all.

Conclusion

Many dental patients report frequent acidic beverage consumption, which is a recognized and major health risk for exposed enamel and dentin tooth surfaces. From this study, dental professionals can find that a post-exposure mouthrinse of ACT Anticavity can return salivary pH to a healthier level after acidic beverage exposure, compared to using no post-exposure mouthrinse. Such a mouthrinse may aid in protection against enamel and dentin erosion and lead to an overall healthier oral cavity. In general, providing dental professionals with information regarding acidic beverages could help them more effectively educate their patients on how to prevent further erosion and create a less hospitable oral cavity for bacterial growth.

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Competing Interests

The authors declare no competing interests.
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Megan Fisher is from Ohio but has spent the last 10 years living in West Virginia. She has been a dental hygienist for 6 years, earning her Associate’s degree from Bridge Valley Community and Technical College. She came to West Virginia University to finish her Bachelor’s degree in dental hygiene. While taking courses, she has continued to work at multiple dental practices to remain active in the field of dental hygiene. She plans to further her education in the future in hopes of becoming an educator one day. Megan will soon be moving back to Ohio with her husband, Dustin, and their two daughters, Sierra, 5, and Leona, 1.

How to Cite This Article:

Investigating the General Public's Perceptions of Bias in Forensic Science

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In recent years, the place of forensic science in the courtroom has been reevaluated. Past research has shown that bias found in forensic science disciplines makes its way into the court system and that pre-judgement expectations influence individuals attending a court trial. Despite these results, relatively little has been done to understand public opinions on forensic bias. To begin investigating these perceptions, a survey was designed to gauge public perspective on bias in forensic science. Multiple choice, ranking, multiple answer, and free response questions sent to the public focused on evaluating a general understanding of forensic science, the existence of bias, root of bias, effect of bias, and future of bias. The results suggest that there is a knowledge barrier for the representative population when it comes to the fundamentals of forensic science and its place in the courtroom. With this apparent knowledge barrier and previous observations of bias entering the courtroom, there is a clear need for something to be done before the role of forensic science is impaired. As this study suggests, the public needs to be better informed on bias and forensic science. Further research will lend more insight into methods of securing the utility of forensic science in the courtroom and taking steps to reduce existing biases.

Introduction

Recently, the overall effectiveness of forensic science in the courtroom has been reevaluated. This reevaluation came about with the rise of several issues in the field, including cognitive bias and pre-trial expectations, which have caused some to question the place of forensic science in the legal system. Many professionals in the field have weighed in on the conversation, and although it is beneficial to hear these opinions, it is arguably more important to have the opinions of those who ultimately make the decisions in the courtroom: the jury, made up of a subset of the general public. Obtaining public perceptions of cognitive bias, the effectiveness of forensic science in the courtroom, and the issues surrounding this topic would provide a foundation for fixing the existing issues in the field.

To gauge public perceptions of bias in forensic science, previous research has involved holding mock trials or interviewing members in the field. In the current study, a survey was shared with a random sample of participants to gauge the level of knowledge which the general public has on topics within bias and forensic science use. The methodology of this survey follows an evaluation of the history of forensic science, the existence of bias in forensic science, the prominent and most-supported side of the “CSI Effect” debate, and the current understanding of the public’s perceptions surrounding these topics.

With questions of forensic science use in the courtroom becoming ever more prominent, it becomes necessary to understand how the public perceives issues in the field so that progress can be made to solve them. After identifying gaps in understanding of topics surrounding bias and forensic science, these gaps can be addressed with specific educational programs.

History of Forensic Science

As defined by the National Commission on Forensic Science, forensic science is “the application of scientific or technical practices
to the recognition, collection, analysis, and interpretation of evidence for criminal and civil law or regulatory issues.”¹ The practice was first recognized in Ancient China, when businessmen used fingerprints to document their work². Since then, the field has grown and evolved into several subdisciplines, each with their own characteristic activities, required levels of education, and areas of expertise. The American Academy of Forensic Sciences recognizes eleven official subdisciplines: anthropology, criminalistics, digital and multimedia sciences, engineering and applied sciences, general, jurisprudence, odontology, pathology/biology, psychiatry and behavioral science, questioned documents, and toxicology³.

**Bias in Forensic Science**

Within each subdiscipline of forensic science, there are different scientific techniques and tests which are routinely performed. “Many forensic disciplines,” the National Academy of Science admits in a 2009 report, “are subjective and vulnerable to bias and other psychological influences.”⁴ Authors Saul Kassin, Itiel Dror, and Jeff Kukucka added in their journal article that this report critiqued the more subjective disciplines, including “toolmarks and firearms; hair and fiber analysis; impression evidence; blood spatter; fibers; handwriting; and even fingerprints,” recounting that, due to the problems in standardization, reliability, and accuracy, contextual bias can be found⁵. Kassin and co-authors also describe Tversky and Kahneman’s conjecture that the bias found in forensic science makes its way into the court system, as well as other research which shows that so-called “pre-judgement expectations” influence all individuals attending a trial⁵.

Many studies and mock trials have previously been performed to investigate the existence of forensic bias in the courtroom. The first such study was conducted by Larry Miller in 1984. His study of 12 college students trained in handwriting forgery revealed that those “exposed to additional inculpatory evidence formed a belief in the suspect’s guilt, which skewed their perceptions.”⁶ The success of this study led to further research on the topic of forensic bias.

A recent study by Kukucka and Kassin took a different approach by investigating the evaluation of a handwritten document with regards to a given confession. The experiment consisted of providing lay participants with a note written in a robbery case and then informing them that the suspect “confessed” and providing them with a sample of the suspect’s writing. After hearing that the suspect confessed, “participants perceived the handwriting samples as more similar and were more likely to conclude, erroneously, that they were authored by the same individual.”⁷

The two studies described above suggest that bias exists in both forensic science and in the courtroom. Whether it be expectation bias, as Miller’s study exposed, or contextual bias, as Kukucka and Kassin’s study revealed, or even the selection and confirmation bias which many other recent studies examine, it is evident that bias exists. This bias not only affects the credibility of forensic science, but also the jury and their important role in courtroom decision-making.

**The “CSI Effect” and Juror Expectations**

Along with the problems of bias which have arisen in the forensics field in the past 15 years, there has been a concurrent rise in juror expectations which has led to additional problems in the courtroom. A debate over the origin of these developed expectations revolves around the existence of the aptly named “CSI Effect.” The CSI Effect is the “perception... that, due to the apparent availability of forensic evidence on crime television shows such as CSI, jurors may be either unwilling to convict in the absence of such evidence or overly reliant on it when it is presented.”⁶ Many researchers, lawyers, police officers, judges, and members of the general public have taken public stances on whether or not this phenomenon actually exists, and whether it affects juror expectations or decision-making.
In their article, Ian Hawkins and Kyle Scherr connect the thought of pre-trial publicity to the idea of the CSI Effect, noting that “it seems likely that experience-taking while viewing crime dramas could have meaningful implications and moderate any CSI effect on jurors' decision-making.”⁷ To test this idea, the authors presented a group of subjects with forensic and/or eyewitness evidence. They reported that “frequent crime drama viewers offered more confident not-guilty verdicts compared to infrequent viewers.”⁷ These results offer support for the existence of the CSI Effect.

![Figure 1. How do you view forensic science’s use in the courtroom? (33 responses)](image)

Figure 1. How do you view forensic science’s use in the courtroom? (33 responses)

Similar to Hawkins’⁷ and Scherr’s suggestion that “experience-taking” causes a different perspective and therefore, evaluation of the evidence presented, Evelyn Maeder and Richard Corbett investigated the possibility of jurors acquitting with no forensic evidence or convicting with forensic evidence, no matter how flawed, in their recent article⁶. The results of their study appear concurrent with Hawkins and Scherr: “increased exposure to crime television resulted in an increase in expectations with respect to scientific evidence,” which affected the act of conviction without forensic evidence. However, the study also made the connection that “participants generally had high expectations with respect to scientific evidence... irrespective of CSI viewing frequency.”⁶ This shows that while their study supports the existence of the CSI Effect to an extent, juror expectations are perhaps more nuanced.

Empirical research is currently being conducted to determine if popular crime dramas create unrealistic expectations which actually affect the court. However, the CSI Effect is a focus point of this study, and previous research supports the fact that jurors enter the courtroom with expectations which can affect their decision making, no matter where those expectations may have originated.

**Knowledge of Public Perceptions**

There is no question of the effectiveness of forensic science when one looks at the amount of success and aid it has offered to the legal system through its years of existence. However, with the discovery of bias in forensic science and the expectations with which jurors enter the courtroom, forensic science could be in danger of having its usefulness in the courtroom diminished.

The future of forensic science relies on the people. One survey recorded that, of the 89 judges surveyed, “61%... felt that CSI–type shows had led to unreasonable expectations surrounding forensic evidence,” and a separate interview of police officers revealed that they believed CSI–type shows to also diminish the police force’s dependability⁶. The results of these studies show that people in the legal system understand that there are issues which need to be resolved. Although these results help identify what those in the legal system believe, it is perhaps more important to understand what the people who make up the jury believe.

Forums or blogs represent one way to gauge public opinion on a topic. In the comment section of one such blog, “Biases in Forensic Science,” John Jenkin posted his belief that “the chief problem is that forensic science [is not] science at all, but just a way that prosecutors try to snow judges and juries with pseudo–scientific nonsense (see, e.g., bite analysis, fiber analysis, blood typing ‘evidence’).” John also believes that “the closest thing they have to real science is DNA, and the[y] consistently misrepresent that.” A
forensic chemist with username Trey posted on
the same blog that “a great deal of the problem
lies in the fact that most crime laboratories are
managed by law enforcement.” Both of these
statements give an indication of what the
people are saying and thinking. However, it is
important to note that these commenters may
have background in the field and most likely
have their own biases.

What this study attempts to do is take these
issues directly to the general public, especially
those with no connection or provided
information on the subject of bias and forensic
science. Although some people will be more
informed than others on these topics, a survey
allows for a good representation of what people
believe through their own experiences. Once it
becomes known what people think of bias in
forensic science, we will be one step closer to
devising a solution to address the problems
associated with bias and expectations,
especially considering that the manner in
which the public views these problems can be
an issue in and of itself.

Figure 2. Where does your knowledge of forensic
science come from? (33 responses) (multiple
choice). Note: "social media" had zero responses

Methods

In order to gauge public perspective on bias
in forensic science, a survey was created and
sent directly to the public. The survey was
generated on Google Forms with multiple
choice, ranking, multiple answer, and free
response questions. The questions were created
with the intent of discovering the knowledge
and perception of people in society. They
probed a general understanding of forensic
science, as well as the existence, root, effect,
and future of bias (Supplementary table).

Figure 3. How much bias do you believe exists in
forensic science? (33 responses) (multiple choice).
Note: "Not at all" option received zero responses

Participants (n=33, mean age=26) were
enlisted on a volunteer basis through direct
messaging after advertising on social media.
For one week, the survey was promoted on two
social media platforms: Instagram and Snapchat. When someone indicated their
interest in the survey, they were sent a link to
the form. The study called for a minimum age
of 17 to participate. In addition to providing
their age, participants were asked to provide
their major and class standing (level of
education) at their discretion. Respondents
were made aware of the rules and obligations
of the study in an introductory paragraph at the
beginning of the survey which stated the
reason for the research, the need for honest
answers, the anonymity of responses, and their
relinquished rights to use of the responses.

Results

After accepting responses for a week, the
survey results were analyzed. When asked to
rank the usefulness of forensic science in the
courtroom, 48.5% of respondents reported a 10
(“Extremely Useful/Effective”), while 51.5%
ranked usefulness above a '5' (Figure 1).

The second question gauged where
participants had gained their knowledge from.
The final multiple choice question showed that, despite the issues it might have, all survey respondents believed that forensic science still has a place in the courtroom (data not shown). Responses to the two questions asking for opinions on how to eliminate bias and how to change public perception surrounding bias and forensic science are available upon reasonable request.

Figure 4. If you believe there is bias in forensic science, do you believe it affects the courtroom and/or jurors? (33 responses) (multiple choice). Note: “Not at all” option received zero responses

69.7% of participants reported that their knowledge of forensic science came from TV or movies. Both “Newspapers/Magazines/News” and “Family/Friends” received 9.1% of total responses, while the last 12.1% of participants selected “Other” (Figure 2). For the third survey question, 90.9% of responses were equally split between “Some,” “Neutral,” and “Not much” bias existing in forensic science. Meanwhile, 9.1% of participants stated that they believed “A lot” of bias exists in forensic science (Figure 3).

45.5% of survey participants reported that bias present in forensic science “somewhat” affects jurors, while 18.2% stayed neutral, 21.2% said it does not affect jurors that much, and 15.2% believed that jurors are affected “A lot” (Figure 4).

Additionally, 35.5% of respondents believed that bias is most prevalent in the process of obtaining and verifying data, 12.9% believed that it is most prevalent within individual fields of forensic science, and 51.6% believed both statements (Figure 5).

Figure 5. Where do you believe bias is most prevalent? (31 responses) (multiple choice)

Discussion

This study attempted to provide an understanding of perceptions surrounding bias in forensic science. Survey results suggest that the population of participants is, as a whole, highly uninformed about these topics. If the respondents are taken to be representative of those in the public who make up a jury, it gives the impression that most people in the public are uninformed about bias and forensic science, which could potentially negatively affect the courtroom decision-making process. For instance, the result that 69.7% of participants reported their source of knowledge as TV or movies is concerning when compared to the result that 100% of people ranked the usefulness of forensic science above a 5 and that 100% said it should be used in the courtroom (Figures 1 and 2). The reason for concern circles back to the discussion of the CSI Effect: if the general public is basing its opinion of forensic science on oftentimes exaggerated forensic science shown on television or movies,
Figure 6. If you believe individual fields of forensic science have the opportunity to lead to the most bias, please select which fields? (25 responses) (multiple answer)

it begs the question of whether jury members actually know enough about forensic science to make decisions for the court.

Other respondent beliefs—including there being anywhere from “not much” to “some” bias in forensic science and that existing bias does not have much of an effect on the courtroom and/or jurors—makes public knowledge about bias and forensic science more questionable. When asked to select the subfields in which they believed bias to exist, respondent answers were widely distributed. Interestingly, the subfields reported by the National Academy of Science as being suggestible did not closely match what the respondents considered to be suggestible. A total of 46 responses were recorded for fields matching the Academy’s depiction of suggestible fields; however, 38 responses identified subfields not typically recognized as suggestible.

All survey responses suggest a knowledge barrier for the general public when it comes to the principles of forensic science and its place in the courtroom. Importantly, if those in the courtroom believe jurors to not have pre-trial expectations, this survey suggests that such a belief is misplaced. Importantly, even if jurors had no true prior knowledge, they may still have expectations.

However, in addition to providing insight on public knowledge, the survey results also suggest a solution. If lack of knowledge is an issue, then the obvious solution is to find a way to inform the public of potential biases and the truth about forensic science. This notion is also evident in the results of the survey; when asked for opinions on public perspective, most participants suggested (to some extent) the simple act of informing the public, whether it be about television shows, the purpose of forensic science, or the potential for bias.

Since this survey was conducted on a volunteer basis through advertisement on social media, possible limitations are that those without a social media account (or in different social circles) would have been excluded from the survey. In addition, there were 76 responses to the original survey, but only 33 were recorded due to technical issues. These limitations do not affect the sample responses which were collected and analyzed, but may reduce the representativeness of this study. If this study were to be performed again, a larger sample group with a wider and more diverse age range of participants would seek to confirm the results presented here.

Conclusion

In recent times, forensic science and its impact in the courtroom has been put on trial. Due to bias in the field and expectations which jurors enter the courtroom with, the need for
change has been uncovered. However, before anything can be done about these issues, it is first necessary to understand how the public perceives the issues of forensic science, as well as forensic science in general. This study contributes to this goal by revealing evidence that the general public is largely uninformed about bias and forensic science. As this study suggests, the public needs to be informed about bias in forensic science. Whether it be to inform the public as a whole, give lessons to jurors of potential issues in forensic science, or change the way in which forensic science is presented on television, future research will aid in finding the best way to inform the public on issues of bias and forensic science. Although this survey provided thoughtful insight into the issues being questioned, it is not the end of the line; there is still a long way to go before the future of forensic science is recognized—at the very least, there is a path towards it.

Competing Interests

The author declares no competing interests.

References


About the Author:

Sarah Riley grew up in a small village (yes, village!) in western Ohio. For her, moving to a different state was the most exciting thing that had ever happened to her. Instead of drowning in the sea of people in Morgantown, she found a home, not just a place to study. She is now in her third year at West Virginia University, where she is studying to be a Forensic Examiner so that she can help bring justice to those wronged through crime scene investigation. She has considered continuing her schooling after graduation, and is not ruling anything out. Sarah loves thinking of new topics to research and is ready to explore new opportunities. She is looking forward to the future of her schooling and her career.

How to Cite This Article:

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<th>Question</th>
<th>Answer Options</th>
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<td>How do you view forensic science’s use in the courtroom?</td>
<td>Rank from 1 (completely useless/ineffective) to 10 (extremely useful/effective)</td>
</tr>
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<td>Where does your knowledge of forensic science come from?</td>
<td>o TV shows/movies (i.e. CSI, Bones, Forensic Files, etc.)</td>
</tr>
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<td></td>
<td>o Newspaper/magazines/news (New York Times, Discover, Fox News)</td>
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<td>o Social media</td>
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<td>o Family/friends</td>
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<td></td>
<td>o Other (type below)</td>
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<td>If “other” was chosen in previous question, please list your answer below.</td>
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<tr>
<td>How much bias do you believe exists in forensic science?</td>
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<td></td>
<td>o Not much</td>
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<td></td>
<td>o Some</td>
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<td></td>
<td>o Not at all</td>
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<tr>
<td></td>
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<tr>
<td>If you believe there is bias in forensic science, do you believe it affects the courtroom and/or jurors?</td>
<td>o A lot</td>
</tr>
<tr>
<td></td>
<td>o Not much</td>
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<tr>
<td></td>
<td>o Some</td>
</tr>
<tr>
<td></td>
<td>o Not at all</td>
</tr>
<tr>
<td></td>
<td>o Neutral</td>
</tr>
<tr>
<td>Where do you believe bias is the most prevalent?</td>
<td>o Process of obtaining and verifying data (analysis, comparison, evaluation, verification)</td>
</tr>
<tr>
<td></td>
<td>o Individual fields of forensic science</td>
</tr>
<tr>
<td></td>
<td>o Both</td>
</tr>
<tr>
<td>If you believe individual fields of forensic science have the opportunity to lead to the most bias, please select which fields?</td>
<td>o DNA analysis</td>
</tr>
<tr>
<td></td>
<td>o Facial recognition</td>
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<td></td>
<td>o Hair analysis</td>
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<td></td>
<td>o Handwriting analysis</td>
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<tr>
<td></td>
<td>o Fingerprint comparison/identification</td>
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<td></td>
<td>o Chemical analysis (drugs, paint, glass...)</td>
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<td></td>
<td>o Odontology (tooth analysis)</td>
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<tr>
<td></td>
<td>o Tool mark comparison</td>
</tr>
<tr>
<td></td>
<td>o Digital forensics</td>
</tr>
<tr>
<td>Do you believe that forensic science is beneficial and should be used in the courtroom?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>How can we eliminate bias in forensic science?</td>
<td>Free response</td>
</tr>
<tr>
<td>What are your opinions on how to change the public's perspective of forensic science?</td>
<td>Free response</td>
</tr>
</tbody>
</table>

Supplementary table. Survey questions sent to participants
"As a proud West Virginia University student, I am reminded of the Mountaineer values of exploration, curiosity, and "going first" every time I see images of mountains. While the bright colors and painterly brushstrokes used in my original painting do not look exactly like the mountains we see surrounding our campus, I think this cover still captures the spirit of this university and the bright-minded undergraduate researchers who go here."
"Research is a creative undertaking; one that much reminds me of art. It is the pursuit of discovery and the hope for answers. To me, this painting encapsulates the spirit of research. The rodents depicted are reminiscent of the classic test subject, which they eventually overcome and control. The perplexing twisting mass being tamed is similar to the way one must make sense of and own the direction of research. The yellow butterflies instill a lingering sense of hope; and hope drives art as well as research."
"Undergraduate Research is the result of the wisdom and hard work of our school students. I arranged Undergraduate Research into a circle to give the impression of a black hole, and the white dots around it symbolize the students who work hard for it. Even if the road ahead is dangerous, the students bravely move forward and use the knowledge they have learned to build the road to their flight. When they are scattered, there are stars in the sky, and when they are gathered, there is a beam of light, moving towards the same goal. I think that science and human exploration is endless, always maintaining curiosity and longing for unknown things, to find answers and this is the broader context of my artwork."

Qian Chen
"Inquiry is an attempt at visually composing the ideals supporting undergraduate research. The piece illustrates individuals undertaking the investigation of an ambiguous scientific endeavor (the means and end to their investigations are left to the imagination of the viewer). In representing engaged and active individuals, Inquiry is attempting to elucidate the core understanding of a discipline in the form of a practice that is aimed at the contribution something meaningful to our world."
The Robert Lepper Mural Painting: a Hidden Gem in White Hall at West Virginia University

Katelyn S. Caplinger
West Virginia University School of Art and Design

White Hall, on West Virginia University’s downtown campus in Morgantown, hides a gem little known to the general population: in one of the classrooms resides a large mural created by painter Robert Lepper. Completed in 1942 and intended to represent the unity of art and science at West Virginia University, this mural is an impressive albeit easily-overlooked piece of West Virginia University history. In this study, we conducted an in-depth examination of the Lepper mural using several visual and analytical techniques, which together reveal interesting technical and artistic aspects of the work. In addition to furthering our knowledge about this historic piece, we hope to bring awareness of its grandeur to the greater university community so that it may be studied and enjoyed for years to come.

Figure 1. Robert Lepper mural painting. Photograph courtesy of the Daily Athenaeum

Introduction

Robert Lepper, who hailed from Pittsburgh, Pennsylvania, was commissioned in 1940 to create the mural in White Hall, which then housed the Mineral Industries Department. He was requested to create a piece showcasing West Virginia’s local industry, science and agriculture. The end result is a captivating piece, reeling with artistic skill and cultural significance. However, because this mural is not in a widely-used public space, many people are unaware of its existence. Indeed, only those who take a class in room G21 of White Hall or actively seek out the mural will ever see it.

Lepper had made a name for himself at a time when mural painting was regaining popularity within the United States. Starting in the early 1930’s, murals were used nationwide as vehicles to uplift the hopes of Americans after a particularly rough economic period. These murals depicted wholesome scenes of American idealism to remind the public of their civic virtues. Under President Franklin D. Roosevelt’s New Deal in the 1930s, thousands of murals were painted across the United States. They were erected in various parks and buildings, mainly in areas which were hit hardest by the economic downfall. One of the most notable instances of government-funded art installations was in the United States post offices. Lepper was one of the artists awarded such a government commission, and he ultimately established murals for post offices in Ohio, Michigan, and New York.

The mural which Lepper executed for WVU had a specific purpose—to express the unity of art and science. From a technical standpoint, Lepper utilized an atypical methodology: instead of being painted directly onto the wall, the mural was painted onto a separate canvas which was then attached to the wall. It is ultimately unknown why Lepper chose this technique; however, this method generally requires less resources, labor, and time, which may have influenced Lepper’s choice. His unique artistic process became an area of
interest during research, as it would have been extremely uncommon to use a canvas-based approach to mural painting in the mid 1900s. In terms of media, Lepper utilized an egg-based paint, which was also a rarely-used technique at the time due to the limited availability of constituent materials.

By the 1930s, Lepper had become an established industrial designer and artist and taught at the Carnegie Institute of Technology in Pittsburgh. His “fascination with [the impact of] technology on society” and its “potential role for artmaking” lead him to develop the country’s first industrial design degree program. To Lepper, industry and humanity had a symbiotic relationship: during a time at which industry was becoming a more prevalent part of everyday life, the worlds of man and machine were colliding and appeared inseparable. Lepper examined this important relationship and used it as inspiration for many of his designs.

Because White Hall was originally home to the Mineral Science program and Lepper’s fascination with machines fit the school’s theme, it seemed a natural choice to commission him to create the mural. Over a period of two years (1941–1942), the artist created an enormous piece which fully engulfs the front wall of White Hall’s G21 classroom (Figure 1).

The mural painting depicts the many industries found in West Virginia, placing an emphasis on mining and agriculture. There are pipes, levers, cranes, mine shafts, trains, and technical diagrams in the painting—among them, men are shown working alongside the machines. Foliage speckles the foreground, and the iconic mountains of West Virginia can be seen on the horizon. A man and woman sit on the outer edge of either side of the painting, surrounded by crops. Overall, Lepper blends two important aspects of West Virginian life into one, picturesque unit.

Mural Materials and Techniques

Much of the information about the materials used for the mural was obtained during a mural restoration in the 2000s. This information was made available by the WVU Art Museum curator, Robert Bridges. According to curatorial records, the art medium was egg-based emulsion applied onto canvas. This choice of medium is interesting, as egg availability would have been more limited during the 1940s due to wartime efforts.

It is questioned as to whether or not the mural has naturally lost its color clarity over time. In general, painting color hues can diminish in clarity over time for several reasons. Varnish, often applied on the surface of paintings for protection, may naturally darken to a yellowish hue over time. Additionally, egg–oil emulsions are also known for darkening slightly over time. Finally, environmental factors—including light and air quality—play a large part in discoloring art. Thus, it’s likely that the colors on the White Hall mural have become somewhat less vivid over the eighty years of its existence.

When observing the mural up close, one may notice that the paint is applied very thinly on top of the ground (a base layer similar to a priming layer). From this observation, it is speculated that Lepper used a one-coat approach, which also could have contributed to creating the muted color scheme seen today. Additionally, pencil marks are visible under the paint layer in some areas, indicating both under-drawing and instances of pentimento (the presence of earlier paint strokes beneath upper paint layers).
<table>
<thead>
<tr>
<th>Sample #</th>
<th>Location on painting</th>
<th>Sample Content</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>left edge, which appeared to be covered by frame; 45cm from bottom edge</td>
<td>canvas fiber, ground</td>
<td>examined with SEM–EDS and FTIR–ATR</td>
</tr>
<tr>
<td>2</td>
<td>left edge, near sample area 1; 50cm from bottom edge</td>
<td>blue paint and ground</td>
<td>examined with SEM–EDS</td>
</tr>
<tr>
<td>3</td>
<td>left edge, near sample area 1</td>
<td>red paint</td>
<td>amount was too small and sample crumbled, only partial analysis was performed</td>
</tr>
<tr>
<td>4</td>
<td>right edge, near very edge; 35cm from bottom edge</td>
<td>dark green paint</td>
<td>examined with FTIR–ATR</td>
</tr>
</tbody>
</table>

Table 1. Mural sample information.

Methods

The goal of this study was to find out more about the materials and techniques used in the mural’s execution: how it was applied to the wall, which type of painting media was used, what the ground paint consisted of, and the type of canvas on which the painting was rendered.

A preliminary visual examination, focused on evaluating the painting’s surface, was aided by a 10x magnifying lens (Triplet 10x–21mm) (Figure 3). The chemical composition of the ground and morphology of canvas fibers was examined with a scanning electron microscope coupled to an energy-dispersive–spectroscopy apparatus (SEM–EDS, Hitachi 4700 coupled with EDAX Oxford) available at the West Virginia University Shared Research Facilities (SRF). The binding medium in the paint was characterized using fourier transform infrared spectroscopy with attenuated total reflectance (FTIR–ATR)^9, also using instruments at SRF.

After obtaining permission from curator R. Bridges, analytical tests were carried out on small samples removed from the painting. Sample material characteristics were examined with a digital field microscope (MiScope MP3) at 40–140x magnification under white and ultraviolet (UV) light. The UV light induces fluorescence of materials, which indicates their general composition. Four samples were collected and analyzed with the assistance of Dr. H. Szczepanowska (Table 1).

Results

The preliminary visual examination revealed that the mural was applied in four large segments as the curatorial notes indicated; indeed, vertical joints are visible upon close examination. There is a line of demarcation around the edges of the mural, most likely from where a frame was originally attached. With the frame gone, an uneven, slightly tattered canvas edge is revealed. Interestingly, the areas covered by frame are lighter in color than the rest of the mural (Figure 4).

Stereomicroscopy was the first analytical method applied in an attempt to understand the general composition and structure of the sampled material. All four samples were imaged, including the paint, fibers and ground. In samples 2 (Figure 5) and 4, the surface morphology shows the layers of paint on top of a white, chalky ground. The paint appeared shiny and reflective, which possibly indicates either an oil base or the presence of a varnish.

Figure 3: Initial visual examination of the mural. Image courtesy of Dr. H. Szczepanowska.

Magnification of sample 1 shows the twisting tendrils of the fibers gripping onto a grainy substance (Figure 6). This grainy material could possibly be the rabbit–skin glue.
used to adhere the canvas to the wall. It could also be a ground under-paint, similar to what we saw in samples 2 and 4. Importantly, the morphology of the fiber on SEM micrograph shows that it is most likely a glue coating (Figure 6).

In order to determine the chemical composition of the paint, EDS analysis was performed on several samples (Figure 7). The presence of iron in sample 2 was likely a result of Prussian blue in the blue paint, while the detection of calcium and titanium in samples 1 and 2 was consistent with traditional calcium-based grounds (titanium is typically used as a white pigment)\(^{10}\).

One of the most interesting findings from the SEM-EDS analyses was a high presence of lead in sample 4, which came from a section of red paint. The use of lead in paint was largely outlawed after the 1940’s due to its toxicity. Therefore, we can infer that this area was not retouched during the mural’s restoration.

The vibrational spectroscopy of FTIR-ATR permits detection of organic-based compounds in a chosen sample. It depicts the ‘finger-print’ regions of a sample as spectra, which can be compared to known samples to determine different constituent compounds of an unknown sample\(^{9}\). However, the interpretation of the FTIR analysis proved to be more challenging than other techniques used during this study; during the search for comparative spectra which could be relevant to samples studied here, one reference was found for egg-yolk\(^{21}\). In sample 4, the peaks from region 1700-1500 cm\(^{-1}\) are listed by several authors as characteristic for egg yolk\(^{12,13}\). Though quite small in our own sample, they were indeed present. All authors also indicted that clarity of spectra is obscured when additives are present. Because Lepper used a ground, various pigments, and organic adhesives, no clear conclusion was possible at the time of testing (Figure 5).

![Figure 5. FTIR-ATR spectra of samples 1 and 4 (top) and reference samples (bottom).](image)

characteristic peaks are in the region 1600-1700 cm\(^{-1}\). Bottom spectra (LEY, LWE, etc.) show peak characteristics for all egg components from published study\(^{13}\). LEY, liquid egg yolk sample

**Conclusions**

This study brings to light the intricacy of the Robert Lepper mural painting at West Virginia University. A thorough examination revealed details of the mural’s construction, materials, and renovation. However, further analysis is necessary to draw definite conclusions as to the type of art medium. Importantly, this work provides proof that works of art such as the Lepper mural are
incredibly complex and worth appreciating. The complexity of Lepper’s materials ultimately validates his sincerity in striving to create a relevant, unique piece for WVU’s community. By creating a mural which is both compositionally and technically dynamic, Lepper emphasized the importance of symbiotic understanding between science and art. It would undoubtedly be a shame to allow Robert Lepper’s mural to be overlooked; it is hoped that the results of this project will encourage the WVU community to never let these things go unnoticed.

Acknowledgements

The author would like to thank Curator R. Bridges for valuable information about the mural, as well as the Technical Art History instructor Dr. H. Szczepanowska for ensuring access to the analytical instrumentation, encouragement and guidance in carrying out this project.

Competing Interests

The author declares no competing interests.

Figure 6. Microscopic examination of mural samples. (upper left) stereomicrograph of sample 2, which contained blue paint and ground, at 140x magnification. (lower left) stereomicrograph of sample 1 at 40x magnification showing fibers with small particles of ground. (upper right) SEM micrograph of sample 2 at 500x magnification showing paint surface morphology. (lower right) SEM micrograph of sample 1 showing canvas fiber morphology; lighter particles most likely represent canvas adhesive

Figure 7. EDS spectra of sample 2. inset, zoomed leftmost portion of spectra
References


About the Author:

Katelyn Caplinger is a proud West Virginia native from Charleston. She is a senior art history major at WVU with minors in philosophy and religious studies. After graduation, Katelyn hopes to pursue work in the field of historic preservation. She desires to help maintain and illuminate West Virginia’s rich cultural heritage through the upkeep of the state’s unique historical sites. Katelyn attributes her interest in preservation to her father, Michael, who has performed several architectural and environmental research projects around the state, and never missed an opportunity to impart his own wisdom onto her.

How to Cite This Article:


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Since its premiere in Stockholm in the winter of 1956, Long Day's Journey Into Night has been the holy grail of dramaturges around the world. It is the quintessential psychological thriller—entirely autobiographical yet universal in its depiction of stubbornly faithful and hateful familial ties. Suffering in the public domain for the duration of his life and career, playwright Eugene O'Neill finally put pen to paper and exorcised his life’s demons in the conceptualization of this preeminent work. Heretofore, most analyses of the play have been of its character, Edmund, as representative of O'Neill himself. This work attempts to delve into the deeper waters of the play, connecting layers of each character's psyche to that of the playwright at various junctures throughout his life as they are made clear via O'Neill's prismatic authorial voice. Through text analysis, connections are formed between lines in the context of the play itself and their underlying meanings in the context of the author's human experience. In this way, this article finds Long Day's Journey Into Night as a character alone in its entirety, an all-encompassing self portrait of the poet. This article aims to articulate the capabilities of dramaturgy as more than text analysis, but as a means to finding deeper artistic significance within the fabric of known and unknown plays alike.

Introduction

Eugene O'Neill's final trilogy is regarded by many as some of the greatest works within American realism. Long Day's Journey Into Night, the middle play, addresses the history of substance abuse and mental illness which plagued his family for three generations—it is known as near–perfect autobiographical work. The play documents the final summer O'Neill spent with his parents and brother in their New England home. Ella Q., O'Neill's (represented in the play by the character Mary Tyrone) surrendered to her morphine addiction and O'Neill himself (Edmund Tyrone, in the play), enjoyed his first publications in the New London Telegraph while battling an onset of tuberculosis. The character of Edmund has been analyzed by critics as a clear dramatic representation of the author as he was in the year the play is set. This article, in contrast, explores O'Neill's achievement of a prismatic autobiography—one simultaneously distorted and clarified through its representation by all characters of the Tyrone family portrait.

Theatre critics, dramaturgs, and audiences oftentimes find it difficult to study the works of Eugene O'Neill without connecting them to his own life tragedies. Each play seems to paint a period of his own journey, and for the coherence of the following reflection, interlaced accounts of the playwright's timeline are essential. Eugene Gladstone O'Neill was born on October 16, 1888 in a New York City Hotel on 43rd Street and Broadway. He was son to James O'Neill (named "James Tyrone" in Long Day's Journey), an Irish–born actor, who sold out to success in the Count of Monte Cristo, but who could have become a great Shakespearean actor. Eugene O'Neill unabashedly depicted this same man in Long Day's Journey:

TYRONE: I could have been a great Shakespearean actor if I'd kept on, I know that! In 1874 when Edwin Booth came to the theatre in Chicago where I was leading man, I played Cassius to his Brutus one night, Brutus to his Cassius the next, Othello to his
Iago and so on. The first night I played Othello, he said to our manager, 'That young man is playing Othello better than I ever did!'

O'Neill the elder achieved great financial success and security for his day, as would his son with his plays. After developing a case of tuberculosis, Eugene was admitted to Gaylord Farm Sanitorium, where he would live for five months. In Long Day's Journey, Edmund has fallen victim to tuberculosis, but has yet to experience time in a sanatorium. In fact, his brother Jamie fights vehemently against his being sent off to one. Ironically, the very place the young men of the play fear the most is where Eugene O'Neill, at age 24, chose his vocation—it was at Gaylord Farm Sanitorium that he decided to become a dramatist. He dedicated himself to the study of Strindberg, who he said in his 1936 Nobel Prize for Literature acceptance speech gave him "the vision for what modern drama could be." Upon his release in 1913, O'Neill wrote eleven one-act plays in the home of a private New London family. James O'Neill financed the publication of six by the Gorham Press in Boston, and in 1914 Eugene enrolled, at his father's persistence, in George Pierce Baker's playwriting course at Harvard. As seen in Long Day's Journey, James Tyrone bitterly takes on the responsibility of having employed Jamie, time and time again, regardless of his supposed disobedience and neglect:

**TYRONE:** If you weren't my son, there isn't a manager in the business who would give you a part, your reputation stinks so. As it is, I have to humble my pride and beg for you, saying you've turned over a new leaf, although I know it's a lie!

**JAMIE:** I never wanted to be an actor. You forced me on the stage.

**TYRONE:** That's a lie! You made no effort to find anything else to do. You left it to me to get you a job and I have no influence except in the theater...

The initial success of O'Neill was in part due to the aid of a father respected in the theatre, and this perhaps festered in a guilty subconscious. Did O'Neill feel forced into the world of the theatre? If he did, he certainly attempted to escape it during his years at sea, which will be discussed later. For now, we are examining O'Neill, the young budding playwright. The amount of groundbreaking doctrine Eugene was exposed to in Baker's course at Harvard is speculated to have been limited, but it was under Baker's tutelage that O'Neill learned the essential components of a substantial dramatic work. Gaining from the course what he found to be enough, O'Neill, as was his custom, left after one year and shuffled on to Manhattan, to live and work amongst the Greenwich Villagers. This team of artists, radicals, and characters included Susan Glaspell, who would settle on Cape Cod in the summer of 1915 and establish the Provincetown Players, an amateur theatre group in need of material. O'Neill would be the one to supply it!

From this point onward, O'Neill's professional life appears an upward spiral of success. One of his very first full-length plays, Beyond the Horizon, won the Pulitzer Prize in 1918 and ran on Broadway for roughly five months. Not long after, he would win another Pulitzer in 1922 with Anna Christie, and yet again in 1928 for Strange Interlude. At a time in which there were virtually no American dramatists, O'Neill became the first, and was internationally hailed as the greatest. With this recognition came financial prosperity, similar to the kind his father enjoyed throughout his own career. Act IV of Long Day's Journey provides not only insight into James Tyrone's own conflict with monetary prosperity, but Eugene's as well. O'Neill the younger villainized materialism in American society in a series of plays, "The Cycle", also entitled A Tale of Possessors Dispossessed, but these plays were mostly thrown out. Perhaps his vehemence against the nation's consumerist culture did not agree with the fragile and broken state in which the Great Depression had left it; and perhaps he himself, having not been financially injured by the economic crash, felt insecure...
about brashly addressing such a sensitive matter. In relation to the subject of money in *Long Day's Journey*, Tyrone seems to vocalize O'Neill's exploration of his own complex feelings towards security:

**TYRONE:** I've never been able to believe my luck since. I've always feared it would change and everything would be taken away. But still, the more property you own, the safer you think you are.

O'Neill's three marriages each demanded monetary stability. His third marriage needed to survive the Depression; therefore, it is only natural that O'Neill would have found a solace in the ownership of land, just as his father had. It was crucial to O'Neill that his source of wealth be founded in true art, and not reaped from commercial success; this underlying insecurity and paranoia regarding his work was undoubtedly on account of his father. James Tyrone had sold his soul to the touring success, *The Count of Monte Cristo*, and he confesses:

**TYRONE:** That God-damned play I bought for a song and made such a great success in—a great money success—it ruined me with its promise of an easy fortune. I didn't want to do anything else, and by the time I woke up to the fact I'd become a slave to the damned thing and did try other plays, it was too late.

As previously stated, Eugene was dedicated to the poetry of drama, and it was that poetry which motivated each of his dramatic endeavors. This romantic inspiration was shared with his father and textualized by Tyrone, but also laced with the poetic devotion of Eugene. "I loved Shakespeare. I would have acted in his plays for nothing, for the joy of being alive in his poetry" (page 150). Eugene's struggle with his wealth could be summarized in Tyrone's line, "a few years later my good bad luck made me find the big money-maker." O'Neill's wealth was just that—"good bad luck," and as defended by Tyrone, "...a great temptation" (page 150). James Tyrone invested money in real estate, and his son similarly invested his luck in land. Tyrone says bitterly, "What the hell was it I wanted to buy, I wonder, that was worth—well, no matter. It's a late day for regrets" (page 150). What Eugene O'Neill wanted was to buy a home.

O'Neill experienced an unideal and unstable upbringing. Within his very first years, he traveled from one hotel to the other, living life on tour with his parents and older brother. His mother, Ella, never approved of actors or a life in the theatre and would forever regard it as a sleazy profession. Mary's lament in Act I verbalizes this animosity but also foreshadows the following analysis of Eugene's complex desire for belonging:

**MARY:** Oh, I'm so sick and tired of your pretending this is a home! You don't know how to act in a home! You don't really want one! You never have wanted one—never since the day we were married! You should have remained a bachelor and lived in second-rate hotels and entertained your friends in barrooms!

Ella's difficulties in bearing Eugene "on the road" are what supposedly resulted in her drug addiction, which Eugene would resent and bear the guilt of his entire life. He was born ten years after his brother James, from whom Edmund, the middle boy, caught the measles and died at little over one year old. Edmund's birthday was a painful day for Ella and instigated her first drug episode. In 1903, at the age of fifteen, Eugene was informed by his father and brother of Ella's addiction. Around this time, Ella had attempted to drown herself in the river near to the family's New London summer home. The event naturally ruined any chance of the temporary home as a haven for the playwright to look back fondly on. The O'Neill men were luckily present to save her, but the episode made it impossible to hide Ella's demons from the young Eugene any longer. This same year marks O'Neill's introduction to hard drinking—he would battle alcoholism until 1926, when he forced himself to make the choice between alcohol and his
work. When he was only 8 years old, Eugene was sent away to St. Aloysius, a Catholic boarding school, which he resented greatly (page 392). A complicated relationship with the church, rooted in its seeming rejection of his suffering mother's devotion and the cold and disciplinary staff, made for comfortless and homeless formative years. From the boarding school, he was sent to a military school, then to Betts Academy in Stamford, CT. After graduating in 1906, he attended Princeton University for nine months, after which he was expelled for "poor scholastic standing." He had been previously suspended for drunken misconduct—legend has it he threw a rock through the window of then-university president, Woodrow Wilson. It seems that Eugene grew to instinctively reject any possibility of a home being made at Princeton, or at any of his other schools; in each place, no family was present. However, despite these rejections throughout his youth, O'Neill never ceased pining for home; As Mary states, "He doesn't understand a home. He doesn't feel at home in it. And yet, he wants a home." (page 61).

On his own accord, O'Neill first attempted to establish his own home at sea. The ocean plays a significant role in the life and work of O'Neill—a photograph reveals the playwright, age seven, with a sketchbook in hand gazing intensely out to sea. The family's summer home, unambiguously named "Monte Cristo Cottage," sat right at the waterfront, and he would return there every summer while at school. After his expulsion, it seems only fitting that he would pursue the life of a seaman. His voyages at sea would remain perhaps his most precious memories, and this sentiment is reflected in a series of works—from Anna Christie, The Hairy Ape, and The Iceman Cometh—but is perhaps most eloquently glorified through Edmund at the conclusion of Long Day's Journey:

EDMUND: When I was on the square head square rigger, bound for Bueno Aires. Full moon in the trades, the old hooker driving 14 knots. I lay on the bowsprit, facing astern, with the water foaming into spume under me. Every mast with sail white in the moonlight towering high above me. I became drunk with the beauty and singing rhythm of it—and for a second I lost myself, actually lost my life. I was set free! I dissolved into the sea, became white sails and flying spray—became beauty and rhythm, became moonlight and the ship and the high dim-starred sky. I belonged, without past or future, within peace and unity and a wild joy, within something greater than my own life, or the life of man, to Life itself!

As it is poetic, Long Day's Journey is accurate—in 1910, O'Neill shipped out on a Norwegian square-rigger bound for Buenos Aires. At the end of the two-month voyage, he worked and failed at a series of odd jobs, and proceeded to live the life of a waterfront vagabond. Later in life he inscribed in a volume of his plays for an Argentinian library, "I doubt that there was a single park bench in Buenos Aires that had not served me as a bed... " (page 30). His next voyage, to South Africa, would ultimately return him to America in 1911, whereupon he took up residence in a waterfront saloon in New York City, known about town as "Johnny the Priest's." O'Neill would later immortalize the institution by designating it as the interior setting of Anna Christie. After his stint in the waterfront slumming, O'Neill set out to sea again, this time to Southampton, England, on an American liner. After returning home from the voyage, two of his seamen companions committed suicide, and not soon after O'Neill himself attempted the same at Johnny the Priest's. O'Neill briefly refers to the attempt in Long Day's Journey, only switching the name of the priest from "Johnny" to "Jimmie":

EDMUND: Duly sarcastic: Yes, particularly the time I tried to commit suicide at Jimmie the Priest's, and almost did.

TYRONE: You weren't in your right mind. No son of mine would ever—You were drunk.

EDMUND: I was stone cold sober.
As chilling as it may be, Edmund's frank and unattached memory of the action serves as an exorcism or confession for O'Neill himself. Simultaneously, Tyrone's denial of the incident embodies the paternal sadness O'Neill later grew to understand as father to a son, Shane O'Neill, who battled with drug and alcohol addiction. Shane himself attempted suicide multiple times throughout Eugene's lifetime. After Eugene O'Neill's suicide attempt, he returned with his family to their New London home in the spring of 1912—the very time and setting of Long Day's Journey.

The above evidence leads to the conclusion that O'Neill associates pain with home. This association perhaps contributed to his "misunderstanding" of home; Mary accuses Tyrone of the same misunderstanding. The curse of a past and a future, O'Neill observes, is the tether of the living, for Edmund reishes in his moment at sea "...without past or future" (page 153). O'Neill concludes that freedom and belonging are fully achieved in death, where there is no past nor future. Being at sea was the closest O'Neill would ever feel to that sense of belonging or home. He had idealized the conceptual home as a place free of pain. Idealistically, homes were then the opposite of his temporary "places of inhabitation," where drugs, alcohol, illness and suicide haunted him. By the time he had written Long Day's Journey, his brother Jamie finally succumbed to his alcoholism. In accordance with the family curse, both of O'Neill's sons suffered at the hands of drug addiction and ultimately committed suicide. Shane after, but Edmund Jr. just months before, the playwright's death. His home in Provincetown had been washed into the sea in a storm, his second home sold, and his third, in Bermuda, given to his second wife in their divorce. All past inhabitations were rendered nonexistent, and even in the more stately mansions he would build, he never rediscovered that sensation at sea. His third wife, Carlotta, loved luxury, and so their first residence of two years was a forty-five-room chateau at Saint Antoine du Rocher, where he felt uneasy. After their sojourn in France, the couple returned to New York, where they began plans for an extravagant mansion on Sea Island Beach, Georgia. "Casa Genotta" as they called it, had romantic intentions—they desired for it to be haven for their new marriage as well as Eugene's work, equipping it with an elaborate study facing the sea—but it proved to be stiflingly hot, and produced only his never-completed "Cycle" series. However, with the cash benefit awarded to him from the Nobel Prize, O'Neill sought to create a new home in which he could find peace (page 129).

Long Day's Journey Into Night was written around 1940–41 at "Tao House" in Danville, California. "Tao" translates as "the right way of life", and the home embodied Taoist ideals which had appealed to Eugene as young man for their rejection of materialism and American consumerism. The study built in this home was purely functional—a small, grey wood-paneled room—and encouraged a humility and inwardness which birthed the objectivity of Long Day's Journey (page 58). He resided here for six years—longer than he had in any home—and this brief peace is echoed in Act I:

TYRONE: It's been heaven to me. This home has been a home again. [his son looks at him, for the first time with an understanding sympathy. It is as if suddenly a deep bond of common feeling existed between them]

Yet, even in the apparent haven that was Tao House, O'Neill's voice, through Mary, moans: "I've never felt it was my home. It was wrong from the start." (page 44) and again through Edmund: "As it is, I will always be a stranger who never feels at home, who does not really want and is not really wanted, who can never belong..." (page 154).

O'Neill spent his last days in Boston; he had chosen the city for its reputation as the medical capital of the country, but no one yet knew how to treat his unrecognizable illness—what we know today to be Parkinson's disease. He and Carlotta took up residence in a hotel where doctors could make calls whenever needed, and it was there that he died in November of 1953. His prophecy to Baker in 1914 had been fulfilled—when he was no longer an artist, he
was nothing. A day before his death, sitting himself up and wildly looking around the room, O'Neill cried out, "I knew it, I knew it! Born in a goddamn hotel room and dying in a hotel room" (page 505). In those words, the conscious voice of James Tyrone, the disapproving and stranded soul of Mary, are heard. Forever grieving the absence of an inherited or adopted home, America's greatest dramatist lived in tragic ignorance of the fact that in his art and his work, he always had a home. Perhaps to the young boy behind the artistic legend, that would never be enough.

In retrospect, all facets of O'Neill's emotional memory inhabit the space between the lines of Long Day's Journey Into Night. Within each character's perception of each other lies his own varied points of view—he looks on each person with several contradictory layers of understanding. Because Edmund, Jamie, Mary, and James all physicialize and vocalize multiple periods of O'Neill's life, his prismatic authorial voice creates one of the most humanistic and psychologically articulate plays ever written for the stage.

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Further Reading:

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About the Author:

Madelyn Dempsey Dundon is a recent graduate (degree in dance and minors in theatre and art history) of the College of Creative Arts and its Class of 2020 Outstanding Senior! She is a performing artist and aspiring dramaturg and historian. She made her award-winning screen debut as the title character in the SONY Pictures feature film Getting Grace. Madelyn studied classical voice at Moravian College and at the Manhattan School of Music. Prior to WVU, she received her dance training at the Pennsylvania Youth Ballet and at the Rock School in Philadelphia. Dundon's recent creative works includes a one–woman play Encountering Shakespeare: How Two Americans Saved the Bard, presented at the Folger Shakespeare Library, where she is a certified reader and alumna of the selective Public Programs Internship. In collaboration with WVU Art History faculty, Dundon wrote and produced a one woman play on the life and work of WVU alumna and renown abstract artist Blanche Lazzell, which she performed at local elementary schools. Most recently, Dundon developed a dramaturgical casebook on Esplanade, the iconic masterwork by American choreographer Paul Taylor, which she performed in WVU’s 2020 Dance Now! concert, earning her an internship with the Paul Taylor Dance Company in New York City. Since graduating, Madelyn starred in her next feature film, Lucky Louie, anticipated for release this summer. She recently joined the team of Donegal Square Celtic Imports in Bethlehem, PA, where she is pursuing her passion for her heritage and Ireland’s history as a writer and researcher for the business’s online platforms.

How to Cite This Article:

Swords, Wars, and Goldsmithing: Benvenuto Cellini and Masculinity in Sixteenth-Century Italy

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Born in 1500, Benvenuto Cellini was one of the world’s most renowned Renaissance artists. As a goldsmith and a sculptor, his works became well-known masterpieces. In his autobiography, *The Life of Benvenuto the Son of Giovanni Cellini Written by Himself in Florence*, Cellini detailed his experiences and actions as an artist, fighter, and man living in the sixteenth century. While Cellini states his purpose for writing the autobiography is to describe his achievements in art, there is a great deal of violence in *The Life*, much of which Benvenuto instigates. As shown by *The Life*, in 16th century Italy, aggression—if justified—was seen as a sign of masculinity in artists, and justification for such aggression could come through communal, political, or religious approval. This essay examines how violence could be justified in the sixteenth century as a form of masculinity. First, the article takes a brief look into the work of historians on Cellini and masculinity. Afterward, the discussion moves to the three ways in which violence could be justified: communally, politically, and religiously, each of which are paired with examples from *The Life*.

Born in Florence in 1500, Benvenuto Cellini would grow to become simultaneously one of the most famous and infamous Renaissance artists. As a sculptor and goldsmith, his work went nearly unparalleled. He entered challenges against artists such as Michelangelo, a competition in which Cellini was the victor. Cellini created artwork for kings and worked for the papacy. One of his most famous works of art is his statue of Perseus standing with the head of Medusa, a piece of art which still stands today in the Piazza della Signoria in Florence. Despite his incredible talents as an artist, his violence and the crimes he committed in sixteenth-century Italy, which he recorded in his autobiography, are equally remembered along with his immense skill. In fact, Cellini began to work on *The Life* after being sentenced to four years in prison in 1557. Throughout *The Life*, Cellini admits to dozens of violent crimes—including murders—but his sentencing in 1557 was for the nonviolent crime of sodomy.

First, we turn to the study of Cellini himself, both as an artist and as a man. In William Caferro’s book, *Contesting the Renaissance*, Caferro examines the way which historians have viewed the Renaissance over time. In it, he notes that Cellini is commonly mentioned in sections of historical text as an “individual.” Caferro even notes that Jacob Burckhardt, a Swiss historian from the nineteenth century who studied the Renaissance, described Cellini as a “whole man,” who could “do all and dares do all, and who carries his measure in himself.” Historians have used Cellini as a way to discuss the behaviors and practices of artists, as *The Life* gave many insights to the daily practices of Renaissance artists. Art historian Beth Holman used Cellini and his artistic competition against Giovanni Bernardi to stress the point that competition for artists was multifaceted. Cellini and Bernardi competed against each other in a smithing contest where they were both to design a medal of Pope Clement VII. While there was a monetary prize involved with winning the contest, the pride won by the victor was far more significant. In addition, the Pope’s attention on the contest allowed for Cellini or Bernardi to win the Pope’s favor. Thus, competitions among artists in the Renaissance were a way to practice one’s skill while simultaneously stressing the artist’s honor and
helping establish or strengthen routes of patronage.

Cellini and his actions continue to mystify modern historians; indeed, this article is not the first to look at Benvenuto Cellini and the way which *The Life* can be used in the discussion of masculinity. Margaret Gallucci looked directly at Cellini’s Life in 2003 for her book *Benvenuto Cellini: Sexuality, Masculinity, and Artistic Identity in Renaissance Italy*. The book looked at Cellini’s autobiography and analyzed it as a piece of literature. However, looking at Cellini’s Life through the lens of gender and sexuality studies has been critiqued. Paul Oppenheimer’s review of Gallucci’s book made clear the stance which opposes this method of interpretation. For example, Oppenheimer disagreed with Gallucci’s argument that Cellini “fashioned” himself through his autobiography, feeling as though the argument lacked evidence. More generally, Oppenheimer questioned whether or not Cellini’s *Life* could even be used to study how men of the Renaissance interpreted gender and its stereotypes as it had not “been invented in the sixteenth century.” Oppenheimer seemingly ignored the ability of a person to act within a social construct even in a time period when the construct had yet to be defined. However, in an essay which focuses on masculinity in Cellini’s *Life*, it is important to note the criticism of this kind of interpretation.

Now, we turn to the study of masculinity in the Renaissance and, more specifically, how artists fit into the historical discussion. Cristelle Baskins looked into masculinity through art depicting Scipio, the Roman general nicknamed Scipio Africanus in the second Punic war. Baskins stressed that masculinity was something which was formed over time, as demonstrated by fifteenth-century Tuscan artwork. Manhood was signaled by moving past boyhood and its impulses. Baskins’ work on Tuscan artists of the fifteenth century and their use of art to demonstrate how masculinity was formed lends itself well to the discussion of sixteenth-century Tuscan artist Cellini.

A discussion on medieval masculinity would be incomplete without acknowledging the work of Ruth Mazo Karras. Similar to Baskins, Karras’ book *From Boys to Men* addressed the idea of masculinity being the opposite of being a boy. While it has been common historical thought to imagine masculinity as the opposite of femininity, Karras argued that masculinity was additionally separate from beasthood and boyhood. Competition, Karras noted, was important in forming one’s masculinity, as it demonstrated oneself as superior to others. This aligns well with what Holman noted in her argument about Cellini and his artistic competitions. Karras argued additionally that masculinity in the medieval period did not take on merely one shape. Instead, what was defined as masculine could change based on region, time, and even profession. Karras determined that those who worked in craft workshops defined masculinity differently than those who were professional fighters or scholars. From such evaluation, this argument must acknowledge that the masculine violence which Cellini described and justified in *The Life* were not necessarily applicable to those outside of his career field. Similarly, Sonya Rose addressed masculinity in historical thought. Unintentionally addressing Oppenheimer’s critique, Rose noted that, while the term masculinity has not always existed, it was and is a constructive, formed force. Directly addressing Karras’ work, Rose expounded on how becoming masculine in the Middle Ages meant demonstrating that one was not a boy. Rose wrote about masculinity, stating, “It [was] a status that must be tested and proved.” Cellini’s autobiography demonstrated this point well, as Cellini frequently tested and proved his masculinity through artistic competition, as demonstrated by Holman’s work, and physical competition, including violence.

To further understand discussions of masculinity and Cellini, it must be noted that the source of Cellini’s *Life* is both a historical and literary text. Stanley Brandes also looked into masculinity and sexuality, albeit in Andalusian folklore. Andalusia is a region in southern Spain with geographic and cultural
similarities to Cellini's region. Brandes made it clear that not all individuals can directly interpret masculinity in the same way as the men of Andalusia did in folklore; in fact, not all men within Andalusia would be able to relate to his interpretation of masculinity within his literature of study. However, the way which masculinity was represented in Andalusian folklore seemingly applied to a large portion of the Andalusian male population that created these stories. Similarly, while Cellini’s description of masculinity in *The Life* may not have been the experience of every man in Renaissance Italy, it likely was representative of the attitudes of some Renaissance artists of the sixteenth century.

What is missed in these discussions of masculinity, even when the discussion of masculinity involves the role which violence played, is a discussion of the justification of these violent acts. Although Rose did discuss violence and its importance in masculinity, her discussion emphasized that violence could be used to enforce masculine norms or used to subvert them. Throughout *The Life*, Cellini describes his extraordinarily violent life, one which involves swordfights, verbal attacks, slingshots, and gunfire, all of which are surrounded by very masculine descriptions of Benvenuto and his cohorts. Cellini was always biased in his own favor, so, as Gallucci noted, it must be understood that every section of the book may not exactly represent reality. It’s also important to note that Cellini wrote his autobiography over a period of several years and recounted events from decades earlier, so the described events could be somewhat misrepresented by his necessary forgetfulness. Finally, the edition read for this essay is a translation, meaning that there may be a linguistic gap causing bias. Despite this, Cellini’s tone and message remain in the text, and his discussion of masculinity, even if not directly touched upon, can be interpreted.

The first route of justification of violent actions, resulting in them being identified as masculine, was communal, as society can decide on whether or not behavior is acceptable. The earliest example of violence in *The Life* was portrayed by Giovanni Cellini, Benvenuto Cellini’s father, when he struck his young son to make sure he would remember seeing a salamander, claiming that, “as far as we know for certain no one has ever seen one before.” After a kiss and a payment from his father for forgiveness, Benvenuto finds his father’s action to be acceptable, as it was justified by his remembrance of the event. As was discussed in Rose’s chapter, masculinity was associated with age and domination. Through this early example of masculine violence, Cellini demonstrated his father’s dominant role over him—one which was earned by his age and his position of power in the household. This idea of the father’s role within the family was established not by either of the Cellini men but rather the larger Tuscan society.

Another example of communal acceptance of violence is seen through a quarrel between Giovanni Cellini and his former pupil, Piero. Piero insulted Giovanni by saying that Benvenuto Cellini is wasting his time on, “all this ifiting nonsense,” in reference to Cellini’s skills as a musician. Cellini claims throughout *The Life* that playing music was an activity he did solely because it pleased his dad greatly. Giovanni Cellini and Piero then verbally attacked each other, both claiming that one day the other’s son will come begging to their own superior son for assistance. About a month after the fight, Piero, while surrounded by a crowd, mocked Giovanni. Suddenly, the floor collapsed in under him, killing Piero. The community, after either hearing or seeing Piero’s death, viewed the incident as proof that Giovanni was justified in his quarrel with his former student, and Piero was not. The defense of the Cellini name came from the communal interpretation of the likely random collapse, which defended the honor of Giovanni and Benvenuto, as the honor of the son was brought in during the verbal altercation between Giovanni and Piero.

Importantly, some violent acts were not justified by the communal group around them, as seen when Cellini meets Piero Torrigiano, a man who used to study with Michelangelo.
Buonarroti. Piero claims to have, “lost my temper more than usual, and, clenching my fist, gave [Michelangelo] such a punch on the nose that I felt the bone and cartilage crush like a biscuit. So that fellow will carry my signature till he dies.” This incident demonstrates Karras’ point that masculinity involved rivalry in the medieval period, and defeating another man was a means through which a man could demonstrate his masculinity. Due to Cellinis’ respect for Michelangelo, he finds this statement to be insulting, and he develops a deep hatred for Piero Torrigiano. After all, Piero was the student of Michelangelo, and this aggression was thus against Piero’s superior. While Rose denoted that some acts of violence were used to subvert masculine norms (one of which required the master to be more masculine than the pupil), Cellini found this incident inappropriate against such a master as Michelangelo. To Benvenuto, this story which Piero told—which was laced with masculine language—did not make Piero appear more masculine, and he did not find Piero’s actions to be justified.

Approval for violent actions can also come through political routes, which was a means through by some Renaissance men could try to demonstrate their masculinity. When Cellini was sixteen and his brother was fourteen, his brother started a fight with a twenty-year-old. While this fight reflects the cultural examples of masculinity which Karras described, as the two young Cellini men were rebelling against boyhood by demonstrating their strength over an older person, this fight proved to be rather political. Cellini describes the fight in very masculine terms, stating, “my brother attacked with such boldness that he wounded [his opponent] badly,” and later states that such bold actions will make him an excellent soldier. After the wounded man’s family attacked Cellini’s younger brother with slingshots, causing him to collapse, Cellini joined his brother in the fight against the family. The Eight, a board of magistrates of law in Florence, banished the family of adversaries for “a number of years.” The wording surrounding the description of the family implies that they weakly attacked a valiant young boy and continued to attack even after he passed out. The Cellini brothers received only six months of banishment at “a distance of ten miles from Florence,” showing that their attack was more justified than that of the family, as their attack was more forceful and purposefully aggressive rather than the needless and cowardly attacks of the opposing family, demonstrating that even the government can support one’s masculinity in some instances.

One of the most powerful ways in which one could signal their masculinity through violence was justification by religion. There were two distinct routes of religious validation—through the Pope and through God. Cellini lived through and met several popes during his lifetime. While France and Rome were at war from 1521 to 1529, Cellini fought to protect Pope Clement VII. In one incident, Cellini aimed his gun and shot a man so well that the man “was cut in two.” At this moment in The Life, Cellini fell to his knees and begged the Pope to absolve him of all homicides he committed in the name of the Church. Pope Clement blessed him, forgiving him of all homicides, “[Cellini] had ever committed and all those [Cellini] would commit in the service of the Apostolic Church.” After being blessed, Benvenuto continued to commit justified killing in the name of the Church, lacing the story with ever-growing masculine language. This demonstrates the attitude of Burckhardt on Cellini, since in this section Benvenuto claims to be just as good a soldier as he was an artist. Whether Cellini truly was an “individual” matters less than the fact that Cellini fits Burckhardt’s description that he could, “do all and dares do all.”

Another example of the Pope justifying violence is seen later in the book, when Cellini comes to Pope Clement VII again, after Cellini admitted to not receiving communion or going to confession for several years. After admitting to all his sins, the Pope is quoted as saying, “I absolve you from every fault you have ever been guilty of.” This vague blessing was, in Cellini’s opinion, the Pope’s justification of all of Cellini’s previous actions, both nonviolent
and violent. Although Cellini would commit more sins after this point, Cellini’s retelling of this story gives insight to how Cellini wanted the world to view him after reading *The Life*. He claimed that the Pope himself had justified his actions—even those which were shameful and violent.

As described by Cellini, early on in the papacy of Paul III, Cellini came to the Pope to be pardoned for his murder of Pompeo, an opposing artist who he believed had harmed his career. In this, he was begging the papacy to justify his violent action, and if he were to receive justification, it would provide Cellini a platform to restore his honor, which, in the sixteenth century, was inseparably linked to his masculine identity. When Pope Paul III spoke of Benvenuto’s actions against Pompeo, he stated, “I know nothing of Pompeo’s death, but plenty of the arguments used to justify Benvenuto.” When a friend of Pompeo attempted to dissuade Paul III from pardoning Benvenuto, the Pope responded, “Men like Benvenuto, who are unique as far as their art is concerned, as not to be subjected to the law—especially not him, for I know what good cause he had.” This line from *The Life* is an outstanding example of masculinization through justified violence, and particularly how religion could be deeply involved in the justification of violence and the restoration of honor. However, this example and the language which it was presented in also demonstrates how this particular example may have been exclusive to artists.

Despite the Pope being the most obvious route for religious justification in Italy, it is demonstrated in *The Life* that validation could come directly from God. Cellini had an ongoing disagreement with Pantasilea, a woman whom he had no interest in making his partner. Cellini housed a man named Luigi Pulici whom Cellini banned from being involved with Pantasilea. Luigi swore to God that he would never attempt to flirt with her, and asked God to strike him down if he did. Disobeying Cellini’s command, Luigi flirted with Pantasilea, insulting Benvenuto in the process. This led to a fight between the two men in which Cellini attempted to stab and kill Luigi, but Cellini failed. After several weeks of Luigi roaming free, his horse threw him, causing him to break his legs and die. Benvenuto declares that Luigi “fulfilled the vow he had made…to God,” and that, “we can see how God reckons up good and evil, and gives every man what he deserves.”

In summary, Benvenuto Cellini’s *Life* gives insight into the actions of a Renaissance artist. While Cellini claims on multiple occasions that the purpose of *The Life* was to exalt his art, it also demonstrated values of masculinity. Historians have provided many sources on masculinity, violence, and Cellini himself. What is widely overlooked, however, is the detail of justification which must occur for a violent action to be masculinized. *The Life* exposes that, in sixteenth-century Italy, violence was a route through which an artist could signal their masculinity as long as the aggression was justified, and *The Life* expressed that validation for violent acts could come through either communal, political, or religious means. Notably, there were dozens of examples of justified violence in *The Life* not mentioned here, which reflects both the magnitude of which this idea was repeated and the amount of violent crimes which Cellini committed. Cellini, who wanted to be immortalized by his works, lived in infamy through the violent actions portrayed in his autobiography, which has given historians a clearer picture of Renaissance Italy through his descriptions of daily life, art, and crime.

References


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Jessica Hogbin is a senior who is majoring in History, Italian Studies, and Religious Studies and minoring in Medieval and Renaissance Studies. After graduation, Jessica hopes to attend graduate school and someday obtain a PhD. During her college career, Jessica has had many incredible opportunities. She studied abroad in Italy in the summer after her freshman year. She participated in the Summer Undergraduate Research Experience (SURE) during the summer of 2019, and, this past summer, she interned for the National Park Service at Fredericksburg and Spotsylvania National Military Park.

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