explorations

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Opportunities are open to all undergraduate students. Be part of a leadership and learning community through *Explorations* as a board member, an author, or an artist! The student board works year-round to meet the journal's annual publication schedule, and develop skills in areas such as leadership, public speaking, critical thinking, time management, editing, marketing, publishing, and graphic design. Board member applications are accepted in early-fall each year.

Publication in *Explorations* is a multi-stage, refereed process. The first step to publication in *Explorations* is the synopsis submission, which is an article pitch. Synopses are reviewed by faculty reviewers and student board members. If invited, prospective authors then submit a full manuscript. Full manuscripts are requested by mid-spring and undergo a second round of faculty and student review. Final articles are chosen from the full manuscript submissions. Provisionally accepted articles undergo further editing and a final review by a team of student editors, Undergraduate Research staff members, and a third-party professional editor. Final articles are due in late-spring each year.

Faculty at Texas A&M can mentor undergraduate researchers and encourage them to apply to the board and/or to submit synopses. Faculty and staff can also volunteer to review submissions for *Explorations*. The review process begins each spring semester.

FROM OUR FACULTY

Gentle readers, I am back! After being honored to write the foreword to the tenth issue of *Explorations*, here I am yet again writing for the sixteenth issue—but this time with a twist: this is the last year I will be associated with *Explorations* as I will be retiring soon. As one of the few remaining members of the small crew who set out in 2008 to revitalize and launch a new version of an undergraduate research journal open to all disciplines, I have seen the journal and undergraduate research in general thrive, falter, change, and grow through the events of the last sixteen years. Our first issue went from conception to publication in one year, a feat only possible because we didn't know it wasn't (as I found out later from communications professionals). Which, in a nutshell, describes research and undergraduate research, in particular.

At a premier research institution like Texas A&M University, the breadth, quality, and creativity of faculty-led research is both inspiring and expected. For our undergraduates, many of whom are first-generation or come from pre-college experiences where research was not part of their education, the idea that they can conduct research or scholarship that contributes new knowledge to their chosen field is not obvious. And yet by the time they graduate, literally thousands of our graduates will have engaged in an undergraduate research experience. Some for a short period of time and others for years, all of them working with faculty mentors who give generously of their time and expertise to help our undergraduates attack current problems and issues, explore new ideas and approaches, and develop new technologies and art forms. Some undergraduates will go on to careers in industry, academia, or the professions that strive (in part) to continue to explore the unknown and discover possible answers. Other undergraduates will choose to implement existing knowledge in novel ways, carrying with them an appreciation of the tenacity, imagination, and focus that creating new advances requires.

As the years have gone by, undergraduate research and this journal have changed. *Explorations* has reflected local tragedies like the Lost Pines fire in 2011 and world-wide concerns such as the sequestration of carbon in forest soil. The COVID pandemic not only shut down in-person classes at colleges and universities around the country but also shut down in-person research for undergraduates. Faculty, students, and programs wavered as the unknowns of how long the shutdown would last and how to safely move forward battled for mental and emotional energy with the difficulty of turning the enterprise of higher education into an online experience in days. Yet, ingenuity and curiosity spurred adaptation by all involved, resulting in computational analyses, online collaboration, and many projects investigating or exploring the effects of the pandemic on everything from inner thoughts and mental processes to worldwide networks of flora and fauna.

Undergraduate research has been a showcase for the resilience and determination of faculty mentors, staff supporters, and undergraduate researchers, as well as their creativity and ingenuity through many challenges, those foreseen and those adamantly not. And for the past sixteen years *Explorations* has been here to memorialize that drive. I can't wait to see what the future brings.

DR. SUMA DATTA

Assistant Provost for Undergraduate Studies
Executive Director for LAUNCH
Professor of Biochemistry & Biophysics
Texas A&M University

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Engineering an Ovarian Tumor Microenvironment-on-Chip

By Ashley Chuong '24

Image Credit: J Bettencourt/peopleimages.com | Adobe Stock # 555607443

INTRODUCTION

Angiogenesis and Cancer

Angiogenesis is the complex process whereby endothelial cells, the cells that line blood vessels, form new blood vessels from existing vessels. This process occurs often during times of ovulation, pregnancy, and wound healing.[1] The angiogenic process is regulated by microenvironmental factors that can lead to the start or stop of endothelial cell growth as a reaction to disease or injury.[2] For example, in cancer, cells grow uncontrollably in a mass, leading to an increase in demand for nutrients and an oxygen-poor local environment.[3] Because of the low oxygen, cancer cells release vascular endothelial growth factor (VEGF) to increase blood vessel density and, subsequently, the availability of resources. As a result, reducing angiogenesis has become a target of numerous cancer therapies.

Organs-on-Chip Devices

Organs-on-chips (OoC) are devices that combine cell culture and microfluidics. These devices can be engineered to model physiological processes and recreate the environment immediately around a cell.[4] OoCs have been developed in the past decade to fill the gap between platforms that do not reflect processes in the human body, such as static cell culture and non-human animal models.[5] In contrast, OoCs can recreate environments that can be engineered to develop drugs and other therapies. This study examines the effect of anti-angiogenic therapy in ovarian cancer treatment by utilizing a microfluidic model featuring angiogenesis.

Study Design

The purpose of this study was to model angiogenesis using OoC devices in the presence and absence of spheroids, three dimensional spherical and balled group of cells, of ovarian tumor cells to build an angiogenesis tumor microenvironment chip (aTME-Chip). This experimental design allowed for the investigation of the effect of a local, low-oxygen tumor environment on disease relapse. Bevacizumab (BEV), an anti-angiogenic modulator, was studied in the aTME-Chip. BEV is used to treat multiple types of cancer due to its anti-angiogenic effects.[6] However, after drug withdrawal, tumor angiogenesis increases again, indicating disease relapse.[7] Using an effective dose of BEV, the aTME-Chip was used with and without ovarian tumor spheroids to observe the effects of an anti-angiogenesis modulator in an organ-chip.

METHODS

Organs-on-Chip Fabrication

The aTME-Chips were fabricated using soft lithography methods.[8] Polydimethylsiloxane (PDMS), a silicone polymer, was mixed at a 10:1 base to curing agent ratio with the PDMS curing agent. The mix was poured atop a silicon wafer with the microfluidic device design. The wafer was placed in a vacuum chamber to remove air bubbles from the polymer for 1 hour and placed into a 70 °C oven overnight to cure. The PDMS slab was removed from the wafer, cut into pairs of devices, and punched with a 1-millimeter hole punch to create the inlet and outlet flow holes. The devices and corresponding number of glass slides were oxygen plasma treated then bonded together. The assembled devices were placed in a 70 °C

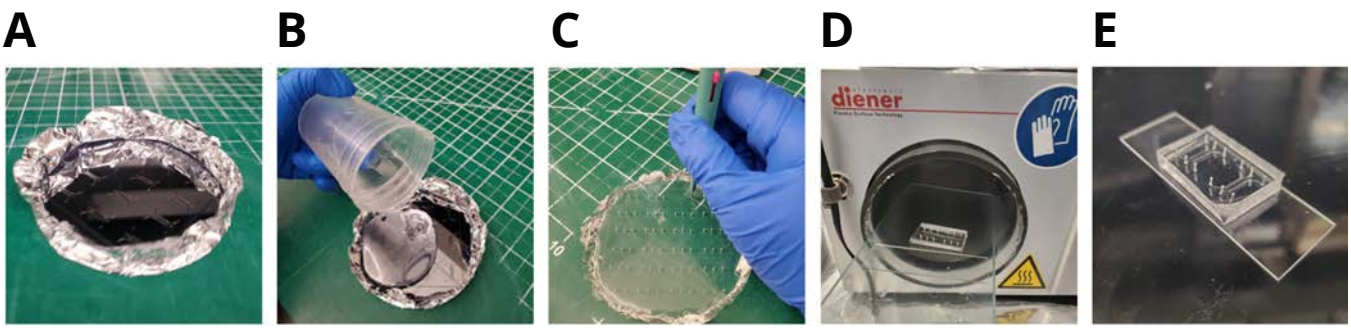

Figure 1. *aTME-Chip Device Fabrication Process Images. (A) Device silicon wafer with an aluminum foil border. (B) PDMS being poured into the mold after being mixed with a curing agent. (C) Inlet and Outlet Holes being punched. (D) Device and glass slide being plasma treated. (E) Assembled aTME-Chip.*

oven overnight. The result was a hydrophobic microfluidic device that has three walls of PDMS and glass with openings at the channel ends for flow. Before use in the experiment, the devices were UV-sterilized for a minimum of 30 minutes. The process is shown in **Figure 1.**

Cell culture in aTME-Chips

Tumor spheroids were assembled using an ovarian cancer cell line derived from ovarian endometrioid carcinoma. The spheroids were made using a 6-well plate that contained 5,900 microwells seeded with 1.5 million cells, leading to a final approximate number of 5,900 ovarian tumor spheroids with approximately 254 cells per spheroid. The spheroids were stained and suspended in 5 mg/mL of fibrinogen.

To begin the process of device cell seeding, 10 µL of the suspended spheroids was combined with 10 µL of 5 units/mL of thrombin to form a fibrin hydrogel. Devices without spheroids were created using the 5 mg/mL dissolved fibrinogen instead of the spheroid suspension. The fibrin hydrogel was injected into the middle channel of the aTME-Chip and allowed to set for a minimum of 3 minutes. A 10% gelatin solution was added to both side channels of the chip and incubated for 40 minutes.

Green fluorescing endothelial cells were injected into one side channel of the chip at a concentration of 10 million cells/mL. After a rinse of saline, the endothelial cells were allowed to attach to the channel while being spun 360 degrees to allow for even attachment along the length of the channel. The seeding diagram can be found in **Figure 2**.

After seeding the devices on day 0, the green fluorescent cells were allowed to grow from days 0 to 2 under conditions that mimic normal growth. On days 2 and 3, 5 ng/mL of BEV were added to the aTME-Chip in the channel with the endothelial cells. The timeline can be seen in **Figure 3**. On day 4, the BEV was removed and replaced with normal growth conditions for the rest of the experiment.

RESULTS

The aTME-Chip was used in two separate experiments: with and without the presence of tumor spheroids. The absence of tumor spheroids served as a control experiment to observe angiogenesis within the chip without the influence of a tumor environment and its corresponding angiogenic growth factors. Both experiments followed the same experimental timeline. In the experiment with spheroids, the tumor cells were formed into spheroids 72 hours before seeding. After growth for 3 days, the spheroids and endothelial cells were seeded into the device on day 0.

In both experiments, 24 aTME-Chips were prepared for seeding on Day 0. On day 2, devices were inspected for proper sprouting and discarded if no angiogenic sprouting had occurred. Devices were then divided into the three testing groups: No Treatment, BEV d2-4 (drug withdrawal), and BEV d2-6 (no drug withdrawal). Each testing group had between 1-3 devices. The "No Treatment" devices received regular EGM-2 media for the entire duration of the experiment. The "No Drug Withdrawal" group received 5 ng/mL BEV

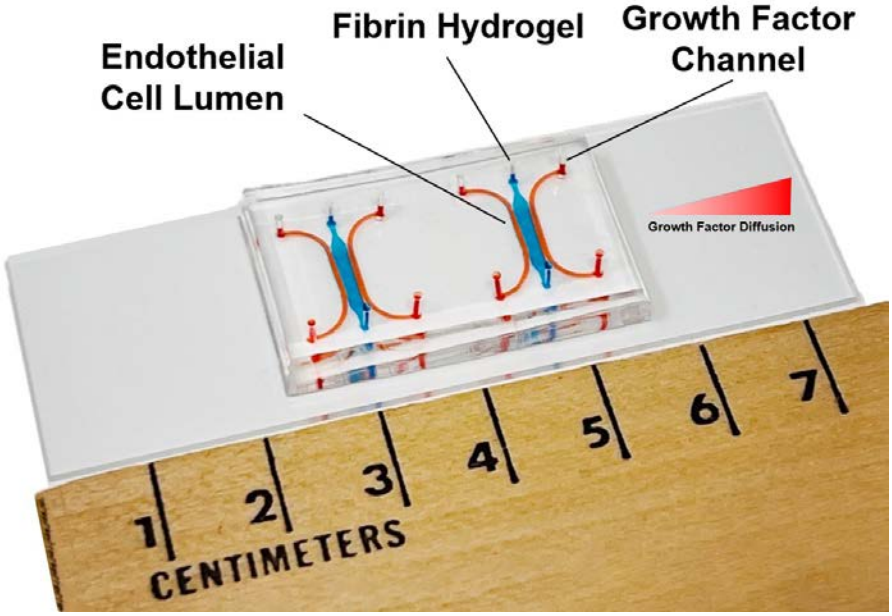

Figure 2. *aTME-Chip Cell Incubation Schematic*

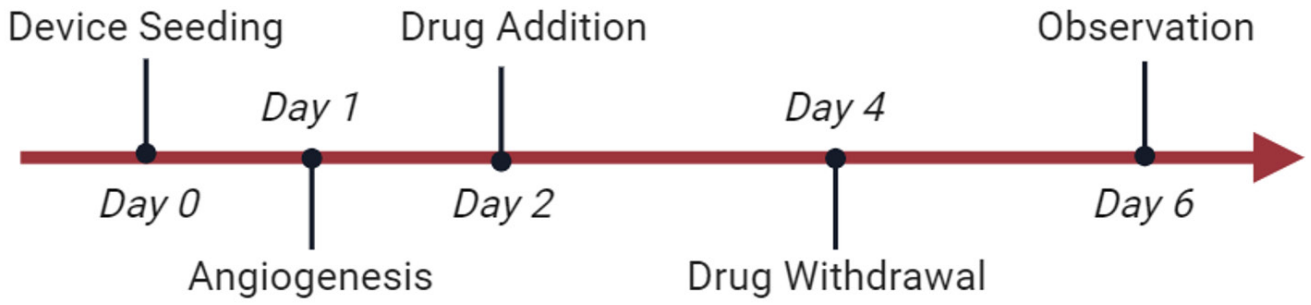

Figure 3. *aTME-Chip Experimental Timeline. Figure 3 was created using BioRender.*

for the remainder of the experiment (days 2-6). The "Drug Withdrawal" group received 5 ng/mL BEV only from days 2 to 4 and fresh EGM-2 media from days 5 to 6. The whole length of each of the chips was fluorescently imaged and the total area with sprouted vessel area was measured. The sprout vessel area between the three test groups was compared using a statistical test (one-way ANOVA) for days 4 and 6 to understand the effects of the drug withdrawal and continual drug administration.

aTME-Chip without Tumor Cells

Fluorescent Images

The aTME-Chip experiment without tumor cells was used to mimic a parent blood vessel, and the results are shown in **Figure 4**. **Figure 4A** depicts the 10 times magnification fluorescent images of the endothelial cell channel in the chip throughout the course of the experiment. When viewing the "No Treatment" column, the angiogenic sprouting increases from day 1 to day 2. This is the expected visual response to growth conditions. For the remainder of the experiment, the sprouts appear to grow further into the middle hydrogel channel. The day 6 "No Treatment" sprouts seem to be more disconnected when compared to the day 4 sprouts, which could indicate that the sprout cells are migrating rather than forming new connected vessels. In the middle column containing the "Drug Withdrawal" results, it can be shown that from days 1 to 2, the angiogenic sprouting is comparable to the sprout growth in days 1 to 2 of the "No Treatment" group. After the 5 ng/mL of BEV was given from days 2 to 4 in the "Drug Withdrawal" group, there was a noticeable visual regression in sprout area. Upon the removal of the drug on day 6, the treated sprouts looked visually denser. For the "No Drug Withdrawal" treatment group that received uninterrupted drug treatment after day 2, the preliminary angiogenic sprouting is similar to the two other treatment groups in density and length. After 48 hours of drug treatment, the images show a different angiogenic sprout morphology and do not look like the "No Treatment" group. The continued application of BEV for another 48 hours showed few to no connected angiogenic sprouts. When comparing the day 6 sprouts between the "Drug Withdrawal" and "No Drug Withdrawal" groups, there is a difference indicating the increased health of the cells that had the drug withdrawn. On the day 6 images, the "No Treatment" group appears to be healthier when compared to the other two groups that received drug treatment. Overall, the representative images from each of the three treatment groups had the expected sprout results.

Angiogenic Sprout Area Quantification

In **Figure 4B**, the quantified sprout vessel area of each treatment group was plotted against the days the experiment was performed. From days 0 to 2, the sprout area increased similarly for all three treatment groups. The sprout area of the "No Treatment" group continued to increase through day 6. From day 2 to 4, both treatment groups that were drugged showed a decrease in vessel area from day 2 to day 4. Upon the removal of the drug, the "Drug Withdrawal" group showed an increase in vessel area while the "No Drug Withdrawal" group had decreased vessel growth.

Statistical Comparison

The one-way ANOVA statistical comparisons for days 4 and 6 of the experiment are shown in **Figure 4C**. At day 4, the "No Treatment" group had significantly

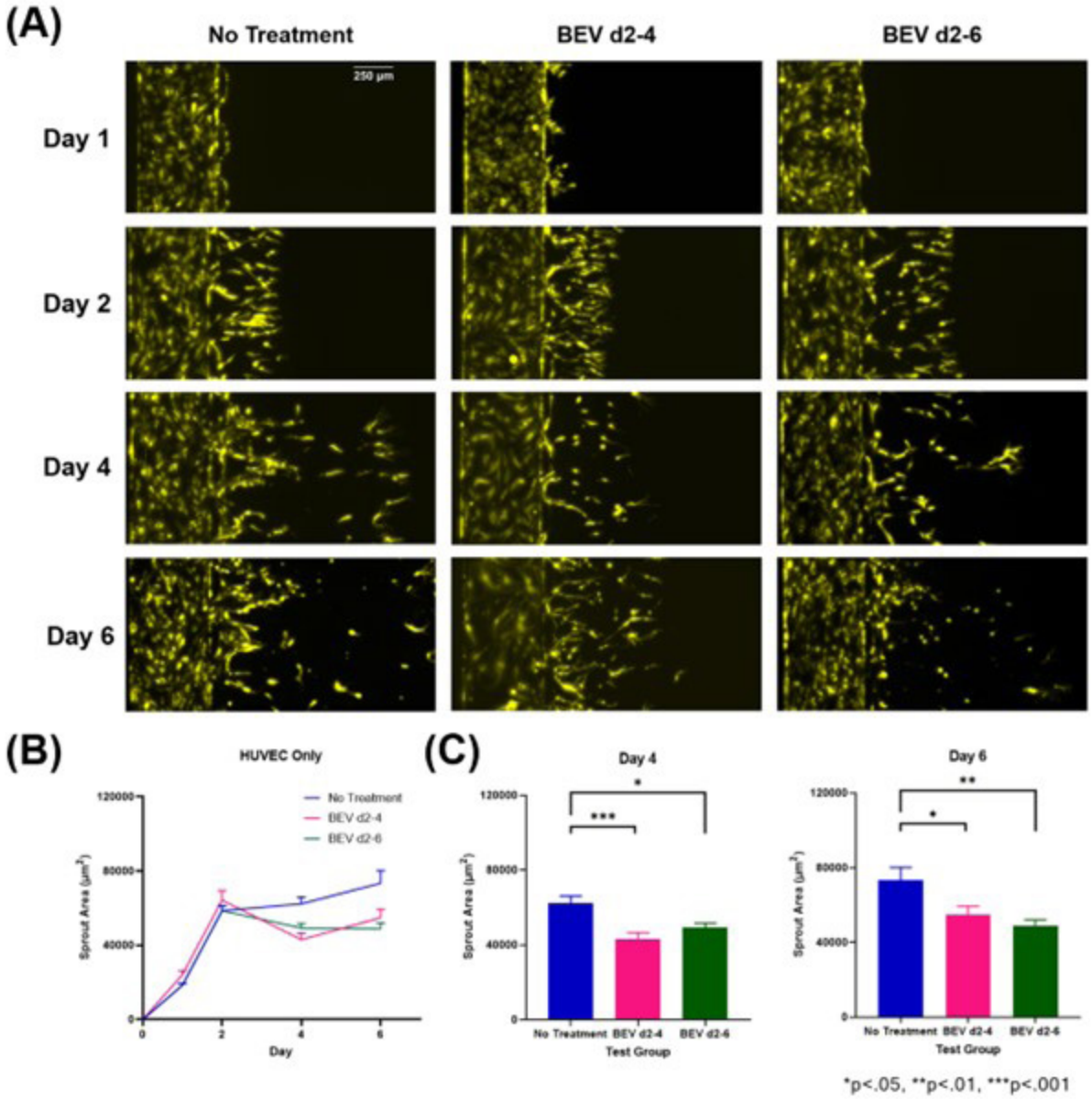

Figure 4. *aTME-Chip Experiment Results (A) 10 times magnification of the No Treatment, Drug Withdrawal, and No Drug Withdrawal test groups (B) Sprout Vessel Area graph of the No Treatment, Drug Withdrawal, and No Drug Withdrawal test groups (C) One-Way ANOVA Comparisons of the three test groups on Days 4 and 6.*

more vessel sprouting than both drugged test groups. This was the expected result since BEV decreases angiogenic sprouting over the two days. The two drugged groups were not significantly different from each other. Upon comparing the day 6 results, the "No Treatment" group was again significantly different from the "Drug Withdrawal" and "No Drug Withdrawal" test groups. This indicates that BEV decreased the final sprout vessel area regardless of the length of time they were exposed to BEV.

aTME-Chip with Ovarian Tumor Cells

Fluorescent Images

The aTME-Chip experiment with ovarian tumor spheroids was successfully completed with results displayed in **Figure 5**. The number of spheroids per chip was not uniform due to the method used to insert the spheroids into the manually with the pipette. In **Figure 5A**, the subdivided 10 times magnification images are shown for the chips of all three treatment

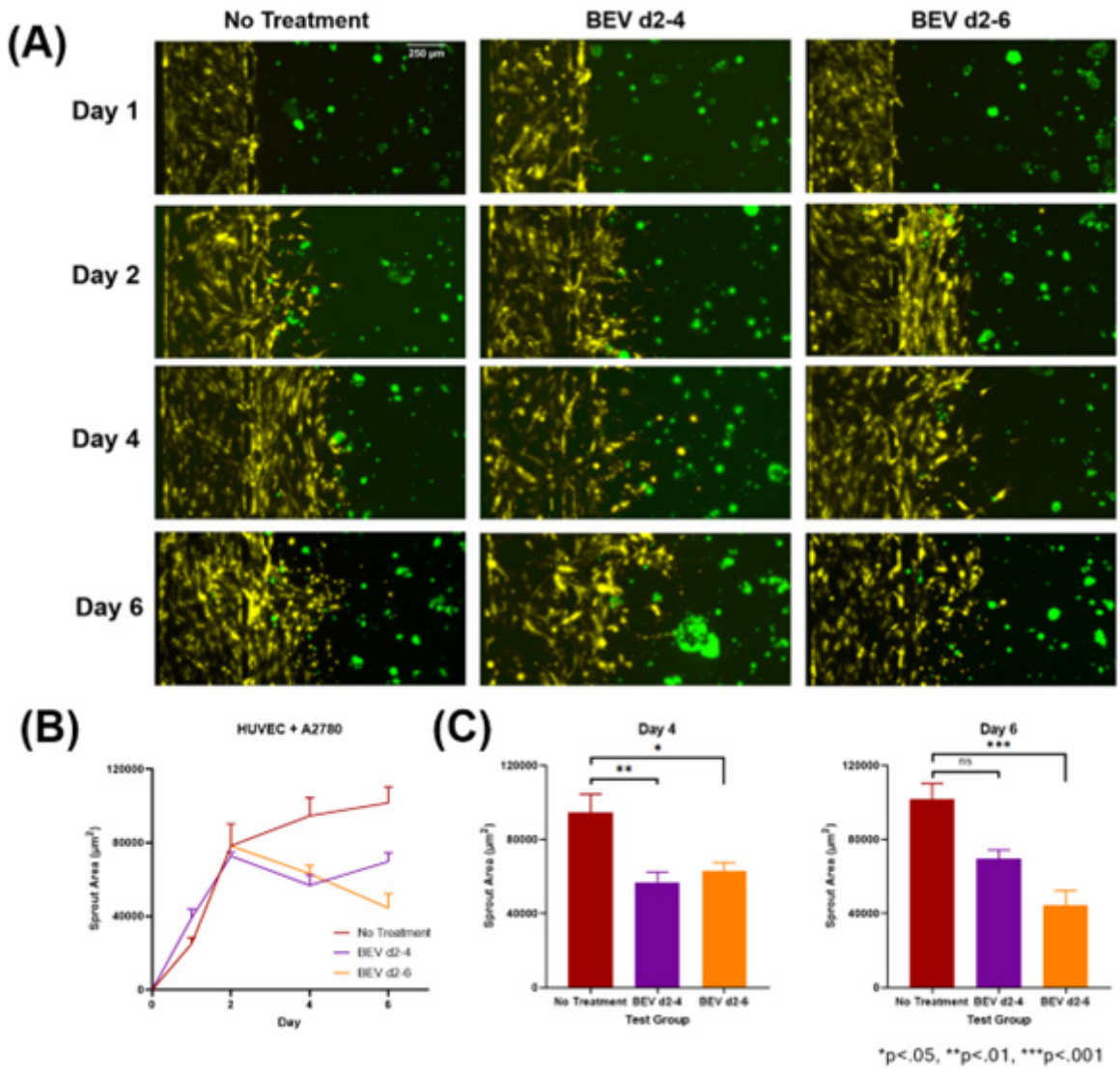

Figure 5. *aTME-Chip with tumor cell Experiment Results (A) 10 times magnification of the No Treatment, Drug Withdrawal, and No Drug Withdrawal test groups (B) Sprout Vessel Area graph of the No Treatment, Drug Withdrawal, and No Drug Withdrawal test groups (C) One-Way ANOVA Comparisons of the three test groups on Days 4 and 6.*

groups throughout the experiment. In the "No Treatment" group, the angiogenic sprouts increased over the course of the 6-day experiment. The sprouts continue to grow towards the middle cancer-containing channel for the rest of the experiment. The sprouts become more disconnected, potentially indicating migration of cells. For the "Drug Withdrawal" treatment group in the middle column of **Figure 5A**, the angiogenic sprouts increase from day 1 to 2 and decrease after applying the drug from day 2-4. On day 6, the sprouts look thicker in nature and denser than on day 4, which is expected due to the removal of BEV. Additionally, in the "No Drug Withdrawal" treatment group, initial growth from days 1 to 2 and a decline after the application of BEV from days 2 to 4 was observed. Upon applying further doses of BEV from day 4 to 6, the sprouts and number of cells in the lumen are fewer in number. In general, the parent vessels of the chips that received BEV showed a sparser lumen by the end of the experiment.

Angiogenic Sprout Area Quantification

The quantified sprout vessel area for the aTME-Chip with tumor spheroids were plotted against time and displayed in **Figure 5B**. All three treatment groups

> **THIS MODEL CAN BE USED TO FURTHER THE FIELD OF PERSONALIZED MEDICINE**

showed a similar increase in sprout area from day 0 to day 2, which can be attributed to the identical conditions from day 1 to day 2. However, the "No Treatment" group continued to sprout vessels for the rest of the experiment. The drugged groups show a decrease in sprouting between days 2 and 4 consistent with the introduction of BEV into the chip. The groups differ again once the drug is withdrawn in the "Drug Withdrawal" test group, as the vessel area increases there while sprouting decreases in the group that continued to receive BEV. Overall, the sprout vessel area for all three treatment groups exhibited the same trends that were shown in the magnified images seen in **Figure 5A**.

Statistical Comparison

In **Figure 5C**, the results of the one-way ANOVA statistical analysis for the sprout vessel area for days 4 and 6 are shown. The day 4 ANOVA comparison shows that there was a significant difference in between the "No Treatment" group and both drug treatment groups. This indicates that the presence of BEV for 48 hours has a significant effect on the vessel area. In the day 6 ANOVA, there is a significant difference between the "No Treatment" group and the "No Drug Withdrawal" group. This points towards the continued application of BEV having a significant effect on angiogenic vessel area.

Additionally, the day 6 "No Treatment" group had no statistical significance when compared to the "Drug Withdrawal" test group. This could indicate the retrogression of angiogenesis being notable enough to not be statistical different to an aTME-Chip that was never treated with BEV. The lack of significance could be related to the presence of tumor cells in the chip and correlated effect of the proangiogenic factors present in an ovarian tumor environment.

CONCLUSION

In this study, we have engineered a successful angiogenesis environment platform: the aTME-Chip. The OoC device provided an effective scaffold for the incubation of endothelial cells to attach and grow new endothelial cells into angiogenic sprouts. Additionally, an effective dose of BEV was found and used in the aTME-Chip to demonstrate the arrest of angiogenic growth. In both the absence and presence of spheroids of ovarian tumor cells, there was angiogenic growth in the first period of the experiment. When comparing the experiments that did and did not have tumor spheroids, the regression of angiogenic sprouting was more severe without cancer cells in the chip. Additionally, the greater amount of angiogenic growth in the "No Treatment" group in the presence of cancer was clear when compared to the "No Treatment" group in the absence of cancer spheroids. When comparing the drug withdrawal and the impact of the cancer spheroid, it is notable that there is a significant difference in sprout area when comparing the "No Treatment" and "Drug Withdrawal" groups without cancer in the aTME-Chip. However, there is no significant difference when comparing the same test groups with ovarian cancer in the system, pointing to the effect of the tumor environment on angiogenesis.

In the future, this model can be refined by enhancing the spheroid formation technique and developing methods that can be used to further standardize the detailed process of device fabrication and cell incubation. Additionally, this model can be used to further the field of personalized medicine by using patient specific cells and different drugs to observe the individual reaction of a unique cancer physiology to standardized and approved drugs.

ACKNOWLEDGEMENTS

I would like to thank my faculty advisor, Dr. Abhishek Jain, and my laboratory mentors, Dr. Lopamudra Das Ghosh and Dr. Jim Tronolone for their guidance and support throughout the course of this research. Thanks also go to my friends, colleagues, and the department faculty and staff for making my time at Texas A&M University a great experience.

ASHLEY CHUONG '24

Ashley Chuong '24 is a Biomedical Engineering major from Mansfield, TX who went to Lake Ridge High School. She has conducted research at Houston Methodist Research Institute, University of London, Birkbeck, and Texas A&M where she has been interested in research involving cardiology, cancer, and organ-on-chips. She is an Engineering Honors Student and an Undergraduate Research Scholar. Ashley plans to pursue her medical degree and a Master of Engineering at Texas A&M's Engineering Medicine program.

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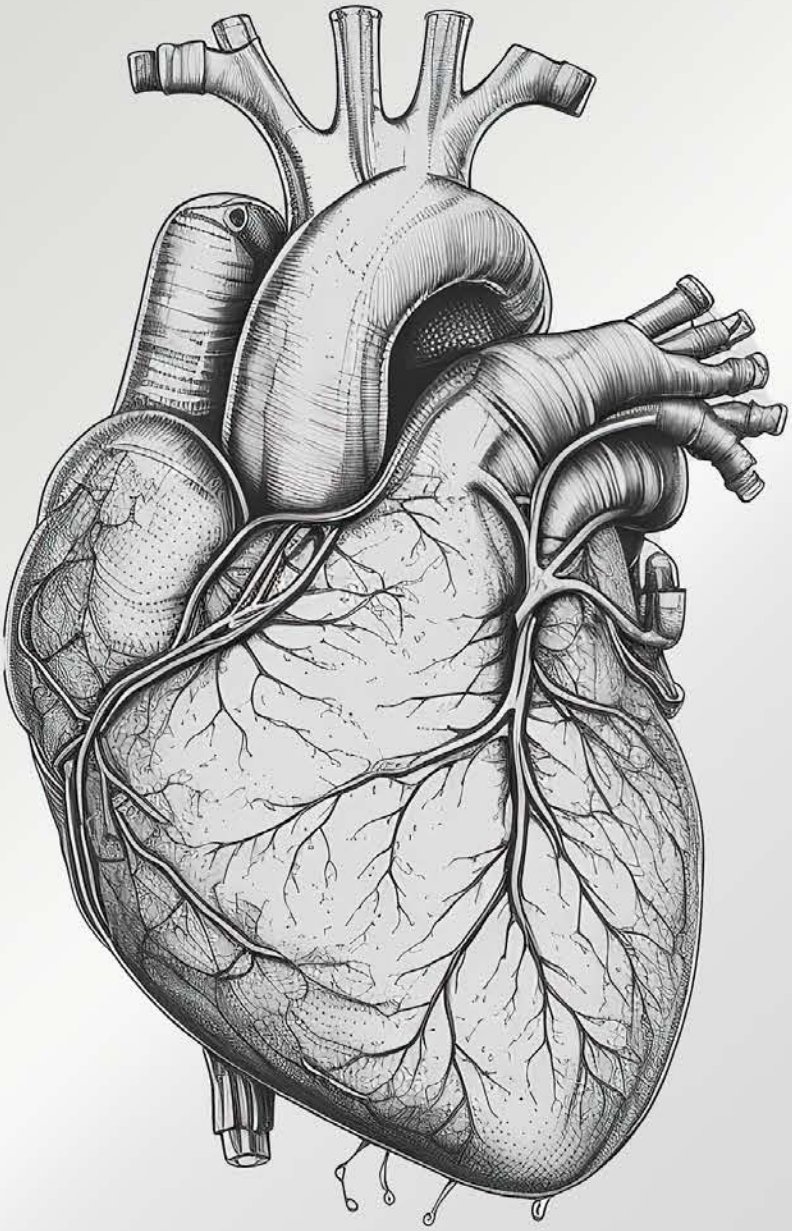
Advancing Cardiac Surgical Training with 3D Printed Tissues

By Aliana Hagen '24



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BACKGROUND

Congenital heart defects are birth defects that affect the structure and function of the heart. Critical congenital heart defects (CCHDs) are cases that require surgical intervention in the first year of life.[1] Young patients with CCHDs are at increased risk for morbidity (development of additional health conditions) and mortality (death) after birth, more than with any other type of birth defect.[2] CCHDs arise in 19.6 per 10,000 live births.[3] Hypoplastic left heart syndrome (HLHS) is one type of CCHD present in 2.61 per 10,000 live births.[4] HLHS is characterized by an underdeveloped left side of the heart. Newborns with HLHS initially appear healthy but are affected by a lack of oxygenated blood, which stems from the left side of the heart's inability to pump blood to the lungs to become oxygenated.[5]

After birth, patients with HLHS will need to undergo three stages of operations, starting from their first week of life to the ages of two to four. The Norwood procedure is the most common operation for the first stage. It involves the construction of a new, larger aorta that connects to the right ventricle (normally developed) and the addition of a shunt to redirect blood flow to the lungs for proper oxygenation (**Figure 1**).[6]

The Norwood procedure is also coincidentally ranked as one of the most difficult procedures (due to active rerouting of blood flow) for surgeons, in addition to having a relatively high mortality score.[7] As such, effective surgical simulation before such procedures is necessary.

> **"THE NORWOOD PROCEDURE IS... ONE OF THE MOST DIFFICULT PROCEDURES FOR SURGEONS"**

Two-dimensional (2D) images produced with computed tomography (CT) and magnetic resonance imaging (MRI) have proven to be valuable tools for preoperative planning but are limited by their two-dimensionality. Three-dimensional (3D) reconstructions made with CT and MRI imaging data have proven to be better, allowing surgeons to visualize each patient's anatomy spatially. Immersive virtual reality (IVR) projects a 3D environment onto a head-mounted display, allowing for real-time manipulation of virtual items, such as surgical tools and the patient.[8] However, all these techniques lack the tactile understanding of anatomy that 3D printed models offer to surgeons.[9]

By 3D printing patient-specific heart models for patients with CCHDs, surgeons will be able to practice on a heart that looks and feels like the actual heart before performing the surgery. Though significant strides have been made in the development of 3D printing techniques and materials in the domain of surgical simulation, there

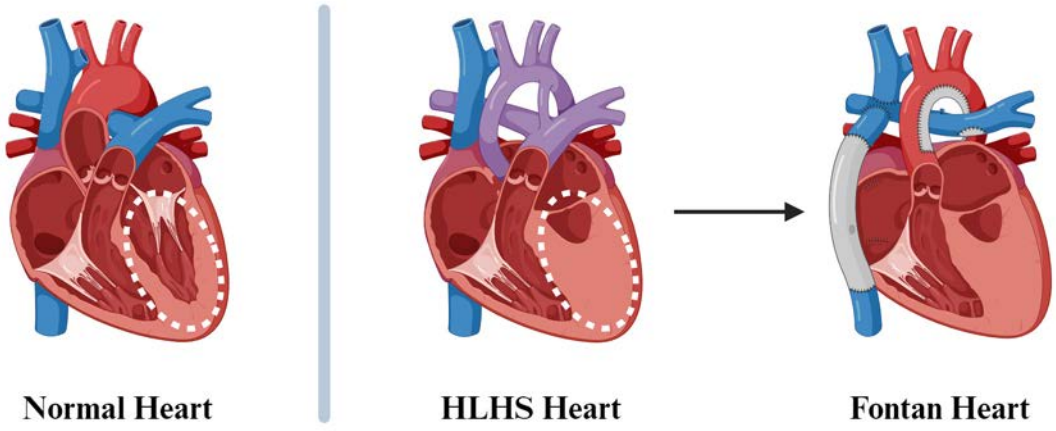

Figure 1. *Comparison between a normal heart cross-section and an HLHS heart pre- and post-operative (created with Biorender.com).*

is a distinct gap for soft tissue models that accurately simulate the mechanical properties, high-resolution anatomical structure, and wet texture of the tissue they are attempting to simulate.[10]

This study aims to address this gap by developing stereolithography (SLA) materials and techniques to fabricate 3D printed cardiac surgical models from patient-specific CT scans to improve surgical simulation for improved clinical outcomes in high-risk cases.

SLA is a 3D printing technique that falls under the category of rapid prototyping. The generalized necessary equipment for SLA includes a computer, laser beam, mobile resin tank, and build platform. SLA works by having a laser beam (underneath the resin tank) harden the liquid resin in the resin tank onto the build platform. The build platform slowly rises as the laser beam forms another layer of the model, until the entire model has been fabricated, layer by layer.[11]

METHODS

To test the mechanical properties of the experimental material formulations, dogbone-shaped testing specimens were produced from silicone, resin (soft polymer or hydrogel), or resin blend. Resin blends were created by mixing resins together with a resin mixer. One silicone, four resins, and four resin blends were evaluated against bovine cardiac tissue:

- **DS**: Dragon Skin™ 10 FAST (Silicone)
- **SE**: 3Dresyn PP SEA10 Super Elastic A10 (Soft Polymer)
- **BE**: 3Dresyn Bioelastic O50 MB Monomer Based (Soft Polymer)
- **BF**: 3Dresyn Bioflex A10 MB Monomer Based (Soft Polymer)
- **HYD**: 3Dresyn SAE1 (Hydrogel)
- **1% HA3**: 1% 3Dresyn HA3 LV MF Bio, 99% 3Dresyn SAE1 (Hydrogel Blend)
- **2.5% HA3**: 2.5% 3Dresyn HA3 LV MF Bio, 97.5% 3Dresyn SAE1 (Hydrogel Blend)
- **5% HA3:** 5% 3Dresyn HA3 LV MF Bio, 95% 3Dresyn SAE1 (Hydrogel Blend)
- **2% BF:** 2% 3Dresyn Bioflex A10 MB Monomer Based, 98% 3Dresyn SAE1 (Hydrogel Blend)

Silicone was chosen as a baseline to compare existing cardiac models fabricated with molding techniques.[12] Soft polymers were chosen as a more elastic alternative to silicone, allowing for further customization. Hydrogels were chosen for their elasticity and wet feel after printing.

An STL file, which describes the geometry of a 3D object, was created for the dogbone specimens using SolidWorks. The STL file was uploaded to PreForm software to create a file readable for a Form 2 printer equipped with a Build Platform 2 (Formlabs). The printer was configured for a print job with "Clear" material and "0.100 mm" layer thickness. These parameters correlate with the level of strength of the laser and the exposure time, respectively. The aforementioned parameters were chosen to be the study's baseline parameters for the development of the materials. After printing, the dogbone specimens were removed from the build platform, washed in isopropyl alcohol for 20 minutes, and stored in deionized water for at least one day so that they could swell to their final size (**Figure 2**).

The experimental materials were evaluated against fresh cardiac tissue in terms of tensile strength, suture retention, and puncture resistance. These parameters correlate with tissue characteristics made apparent during surgery: stretching, suturing, and cutting of the material. These tests were conducted using a 20N force gauge and custom fixtures with the below setup (**Figure 3**). An ANOVA with Tukey's HSD test, a statistical method to determine if there is a significant difference between the means of three or more groups, was conducted to determine which materials had mechanical properties that were significantly different.

To quantify the extent of swelling experienced by the samples, the swollen and the dry weight of the samples were measured (**Equation 1**).

$$\% \, ESR = \frac{w_s - w_d}{w_d} \cdot 100$$

Equation 1. *Percent equilibrium swellability ratio.*

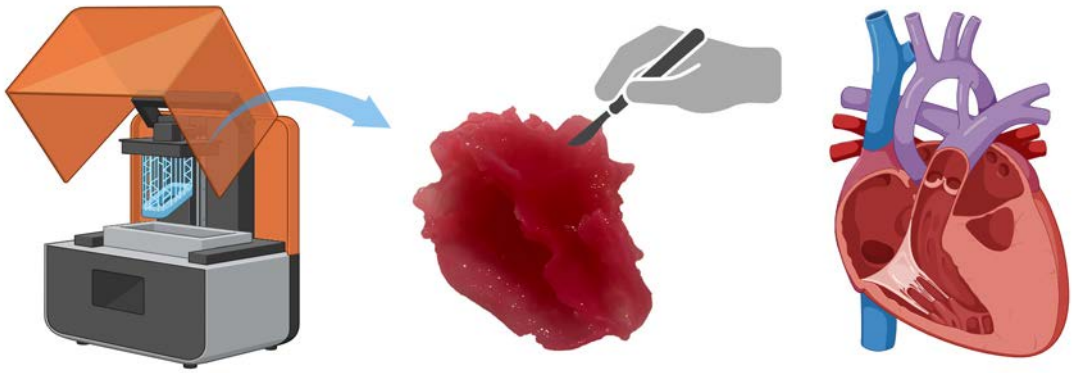

Figure 2. *Method for the fabrication of patient-specific heart models (HLHS) with an SLA printer (created with Biorender.com).*

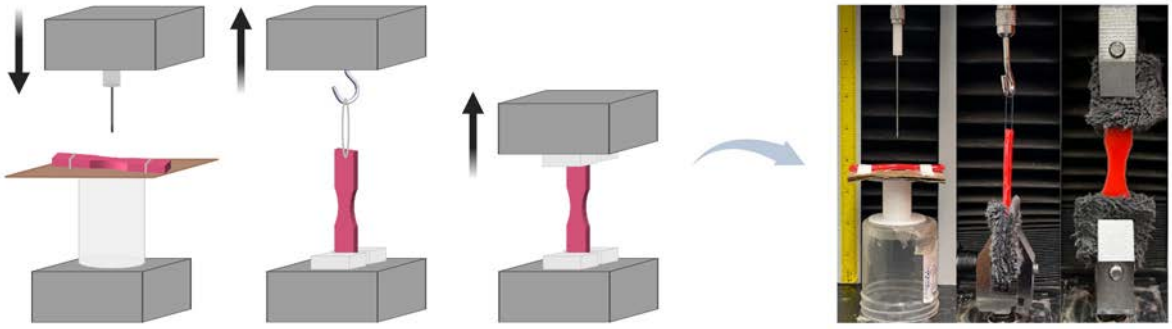

Figure 3. *Testing setup for puncture resistance, suture retention, and tensile strength (created with Biorender.com).*

RESULTS

After conducting preliminary testing on the DS, SE, and HYD samples, it was concluded that the HYD samples displayed no significant differences between the mechanical properties of the cardiac tissue. However, when a full-heart model was printed, the material displayed excessive tearing upon handling. Subsequent testing was conducted on various hydrogel blends designed with the intent of decreasing brittleness while maintaining the observed mechanical properties of the HYD samples. The 2 percent BF blend demonstrated adequate puncture resistance and tensile strength (**Figure 4**), as well as improved tactility and increased resistance to rupture upon handling.

The 2 percent BF blend also demonstrated the highest equilibrium swellability out of the tested hydrogel blends (**Figure 5**).

DISCUSSION

The 2 percent BF blend demonstrates significant potential as a material useful for SLA printing of patient-specific heart models. It is important to note that swellability significantly impacts the mechanical properties, so samples were tested at equilibrium at a baseline and to maximize the wet feel of the synthetic tissue.

For future research, further modifications should be pursued to improve the simulation of cardiac tissue and reduce printing time. Additionally, there is a practical

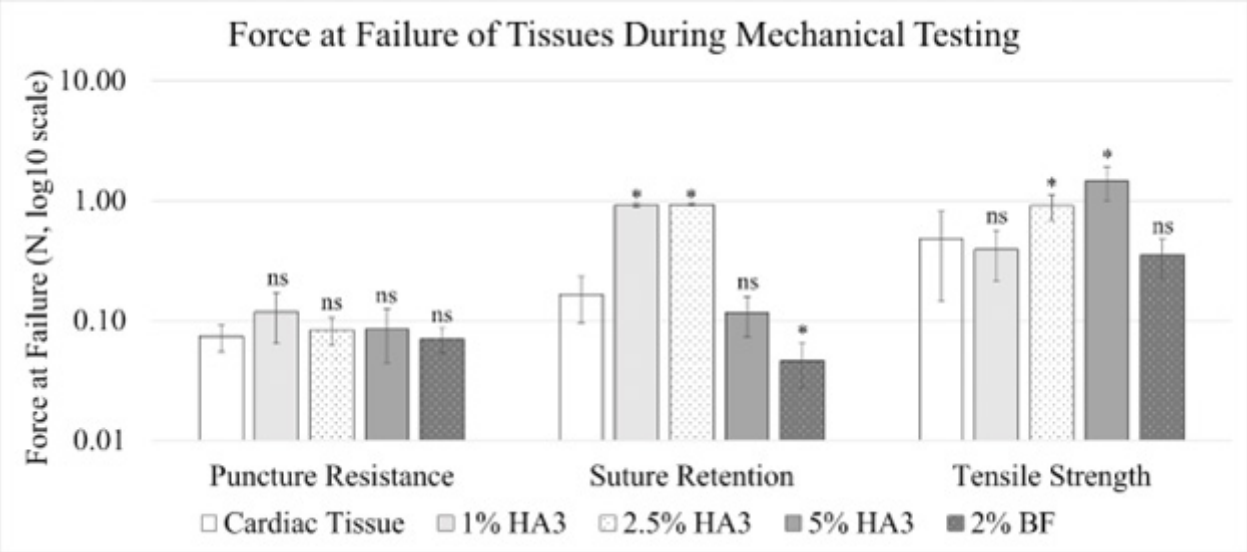

Figure 4. *Mechanical testing results of hydrogel blends.*

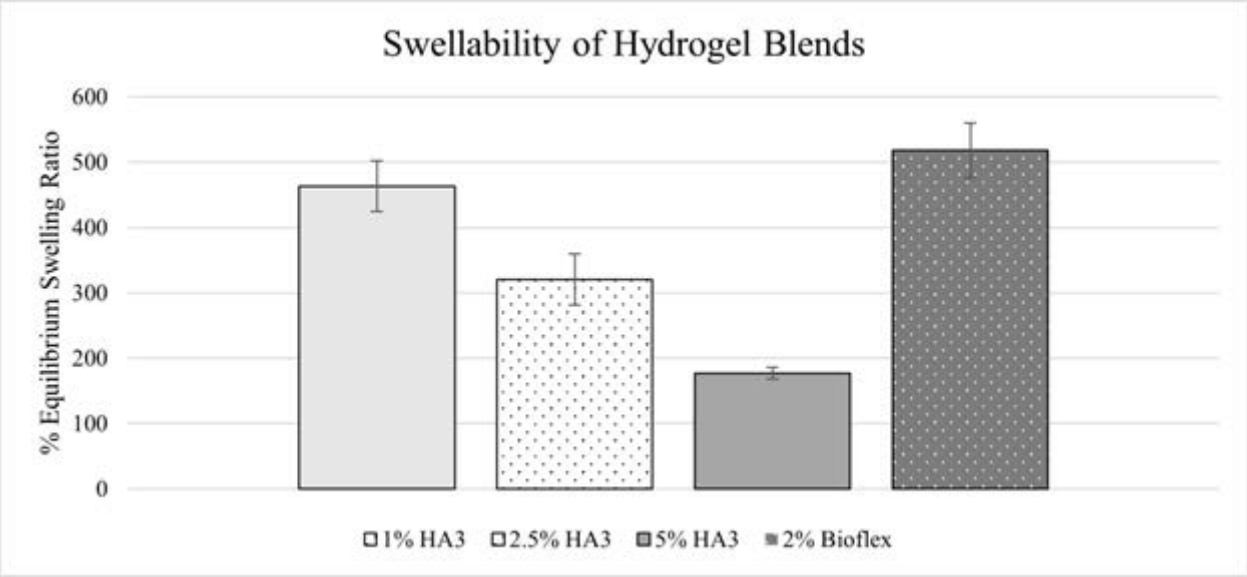

Figure 5. *Equilibrium swellability results of hydrogel blends.*

difference between small-scale testing on dogbone specimens versus large-scale testing on heart models. Thus, more testing is needed to understand the structural integrity of heart models fabricated with such hydrogel blends, optimize printing techniques, and test for more parameters beyond tensile strength, suture retention, puncture resistance, and swellability. The parameters tested in this study offer a sufficient starting point by proposing a material that displays mechanical properties similar to the heart, in addition to the tactile feel imparted by the wetness of the hydrogel. Through the development of a preliminary material that can simulate the soft tissues of a heart, this study aims to help push 3D printed organ models to regular clinical use. To see this, it is imperative that more research is conducted on optimizing print time while maintaining high resolution, mechanical properties, and texture.

By achieving an optimal fabrication technique and material formulation, the barrier to entry for clinical applications will be lowered. With current 3D printing materials and techniques for heart models, it is difficult to quickly print a large volume of custom models. Subse-

> **THE ADOPTION OF 3D PRINTING...WOULD IMPROVE EDUCATION, PRODUCING PRACTICED CLINICIANS WHO PERFORM SURGERIES WITH BETTER CLINICAL OUTCOMES**

quent research should focus heavily on producing vessels or organ structures due to the difficulty of printing entire organs with a suitable material. Regardless, 3D printed models have been shown to improve clinicians' understanding of the spatial complexities of a heart with congenital defects, aid the preoperative planning process, educate medical students and residents, and facilitate physician-patient communication.[13] The adoption of 3D printing in the medical space would improve education, producing practiced clinicians who perform surgeries with better clinical outcomes, and whose patients are able to experience a better quality of life. This full-circle effect has the potential to improve the quality of life of families affected by conditions such as CCHDs.

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The Influence of Naturalistic Stimuli on Cognitive Flexibility

By Humzah Syed Hassan '24

Image Credit: Harrison Leece | Unsplash

INTRODUCTION

Cognitive flexibility allows humans to complete complex behaviors such as multitasking and finding creative solutions. Throughout the day, people are bombarded with naturalistic stimuli such as sound and visual cues from their surroundings. From there, they must decipher and then categorize what to pay attention to. This process is known as bottom-up saliency, where salient regions of an image are identified based on contrasting features, such as color, intensity, and orientation.[1] To illustrate, a red flower would be salient against green grass. Saliency has an evolutionary advantage, allowing humans and animals to spot prey, mates, or predators.[2] Task-switching allows us to focus on what is important in the current moment.[3] In addition, everyday life demands us to shift between cognitive tasks, requiring frequent task-switching. A common example is answering the phone while working on their computer, where they must switch between two tasks simultaneously.[4]

Unfortunately, there is a replicability crisis in psychology. Recently, the replicability of findings in specific subfields, such as social and cognitive psychology, has been questioned, leading to the potential removal of funding and skepticism among the general public. Cognitive neuroscience traditionally used simple parametric tasks using abstract stimuli, such as faces and sounds. Parametric tasks tend to use normally distributed population data. These tasks and stimuli are very controlled and isolated, leaving questions about ecological validity as they do not accurately represent stimuli and behaviors in real life. Most stimuli-based studies focus on memory studies, social cognition, and emotion. As replication studies continue to use the same stimuli, they increase our confidence in the results of these stimuli but would not be helpful when analyzing results from new stimuli.[5] As a result of the overuse of abstract stimuli, naturalistic stimuli were chosen instead. These rich stimuli come in many forms that can represent our daily life. Some examples include movie clips, virtual reality, speech, and language processing.[6] Focusing on naturalistic stimuli, such as pictures, allows us to address the replicability crisis in psychology.

> **“THROUGHOUT THE DAY, PEOPLE ARE BOMBARDED WITH NATURALISTIC STIMULI SUCH AS SOUND AND VISUAL CUES FROM THEIR SURROUNDINGS”**

This study focuses on how animacy and size relate to the categorization of naturalistic stimuli. Animacy can be defined as whether something can be classified as living or nonliving.[7] Being able to categorize stimuli is vital for survival and reproduction such as categorizing a stick from a snake.[8] This study explores whether naturalistic stimuli are more reliable than words when dealing with animacy and size categorization. In addition, the study investigates whether naturalistic stimuli have a larger switch cost, or time interval to move between tasks, than words.

METHODS

Part 1: Image Sorting

Research assistants were split into two groups, sorting through approximately 2,588 images containing salient subjects from the Common Objects in Context (COCO) database.[9] Images were retrieved using Google CoLab and given “1” if there was a salient object and “0” if not. Assistants also labeled the salient object in the image. To be classified as salient, objects must stand out compared to their background. For example, an apple among green leaves would be classified as salient, or 1. On the contrary, a shirt among a pile of clothes would not be salient, as it would be hard to distinguish. Objects that were dull, blended into their surroundings, had incorrect orientation, or were inappropriate, were also removed. In addition, images were classified based on animacy (living or nonliving) and size (larger or smaller

than a human). Afterward, images marked as salient were compared between the two assistant groups based on the label given, leaving 2,440 images to be used. Research assistants excluded images containing two salient objects that could be classified as both living/nonliving or large/small. The COCO database images were used for the pilot phase and phase 1 of testing.

Part 2: Testing

Pilot Phase

Participants

Participants (N = 86) were recruited through the Texas A&M Psychology Subject Pool and were granted course credit for their participation.

Experiment

The study was conducted online with a keyboard on the participant's computer. After consent through Qualtrics, participants completed 11 blocks of 32 trials for a total of 352 trials. Before the experiment began, instructions directed participants to sort the image based on animacy (d: living; f: nonliving) and size (j: small; k: large). The image appeared in the center with four boxes surrounding it (**Figure 1**). The highlighted category indicated the sorting task. The first block guided participants on what images fit specific categories and was thrown out as a test block. Afterwards, the image would go into the corresponding box. The image would stay there for 1.5 seconds before moving to the subsequent trial. The first block served as practice and was removed.

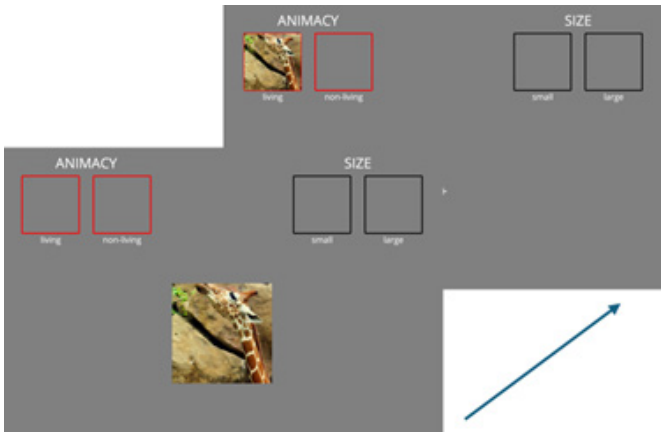

Figure 1*: Image Stimuli Sorting in Pilot Phase*

Testing Phase 1: Images

Participants

Participants were recruited through the Texas A&M Psychology Subject Pool and were granted credit for participation. The study was limited to undergraduate students. Two hundred participants were recruited in total. One hundred completed the study in person and one hundred online. In-person participants completed the study on a Mac. Participants were college-age students (M = 18.5; SD = 0.75), and 135 identified as female (69.6%) with 54 male (29.9%) and one non-binary (0.5%).

Additionally, 120 participants identified as White (51.1%), followed by 63 of Hispanic, Latin, or Spanish origin (26.8%), 20 of Asian origin (13.2%), 12 of Indian subcontinent origin (5.1%), 9 of Black or African American origin (3.8%), 6 of Middle Eastern or North African origin (2.6%), 3 of American Indian/Alaska Native origin (1.3%), and 2 of Native Hawaiian or Other Pacific Islanders (0.9%).

In the Qualtrics survey, online participants were asked about their location, distractors, and what device they used to complete the study. Distractor-based questions included, "Are you currently alone?"; "Is there any music or other sounds in your current location?"; and "How much ongoing activity is around you (e.g., passing cars, people, TV, pets)?"

The only requirements were normal vision, a computer running either Windows or MacOS (for online participants), and the ability to speak English.

Experiment

The experimental setup was the same as the pilot phase.

Data Analysis

Only one participant failed to complete the Qualtrics survey in its entirety. Ten in-person participants' data was removed due to PsychoPy issues or participants lacking focus, resulting in 195 sets of data.

Testing Phase 2: Images and Words

A new set of words was chosen based on a study examining semantic features. These features are distinctive characteristics that allow us to identify an object. Semantic features have proven useful for concepts, categorization, and semantic memory in humans. Researchers focused on 541 basic level concepts, such as "dog" or "chair,"[10] for living and nonliving. From there, concepts were narrowed down based on the word length being between 3 and 10 characters. Afterward, images were added based on these concepts to create a new image set with a minimum of 10 images per concept. Concepts were modified or removed if two different objects could come to mind or if they had multiple variations of the concept. In addition, similar concepts, such as a "yacht" and "boat," were combined.

Participants

Participants were recruited through the Texas A&M Psychology Subject Pool and granted credit for their participation. The study was limited to undergraduate students. Sixty in-person participants were recruited. Participants were college-age students (*M = 18.9; SD = 0.83),* and the majority identified as female (50%), with the remaining male (47%) and preferred not to specify (3%). Additionally, the majority of the ethnic identification was White (52.6%), followed by Hispanic (23.7%), Asian (13.2%), Indian (7.9%), and Black or African American (2.6%). The only requirements were normal vision and the ability to speak English.

Experiment

Participants were placed in a room with a monitor, a keyboard, and a Windows desktop running PsychoPy[11]. They were 28 to 35 inches away from the display. After consent was obtained through Qualtrics, participants were either given version A or version B. For version A, participants were presented with the five image-based blocks followed by the five word-based blocks. Version B had the words presented first and images after. Each block consisted of 32 trials. Before the experiment began, participants were instructed to sort the image/word based on animacy (d: living; f: nonliving) and size (j: small; k: large). The first block of each was used to guide participants on what images and words fit in certain categories and were thrown out as test blocks. This resulted in 256 trials. If the participant were correct, the image outline would not change. The sorted word/image would have a red outline if incorrect. The image would stay there for 1.5 seconds before moving to the next trial (**Figure 2**). Correctness was based on the categorization of the word by animacy and size. The same process was used for words.

Data Analysis

Five participants' data were removed due to technical errors regarding the study. As a result, 55 sets of data were analyzed.

Figure 2*: Stimuli Correctness Feedback Phase 2*

RESULTS AND DISCUSSION

Pilot Phase

A sheet was created showing the maximum agreement between participants. Max agreement is defined as the amount of correct responses in a category divided by total responses. Images that fell below 70 percent max agreement were removed. The median max agreement between animacy and size responses (IQR) was 90 percent (84-95). As a result, 977 images were left and could be used for testing phase 1.

Testing Phase 1: Images

A linear mixed-effects model (**Figure 3**) was used to predict reaction time as a function of task and alternation type, β = -62.441 (*SE* = 4.869, $t(123{,}324)$ = -12.824, p < 2e-16). Any value below 200 ms or above 5000 ms was removed. This result showed a significant difference in the alternation effect. To elaborate, the p-value showed a significant difference in reaction time between switch and repeat tasks. For this phase, switch tasks can be defined as when participants change from categorizing the image based on animacy to size or vice versa. With repeat tasks, participants continue categorizing the image in the same category.

A mixed model ANOVA test was conducted to calculate the interaction between task, alternation type, and platform (**Table 1**). This ANOVA test was a type 3, which tests if a main effect is present after considering other main effects and interactions.[12] The F-value shows the ratio between explained variance and

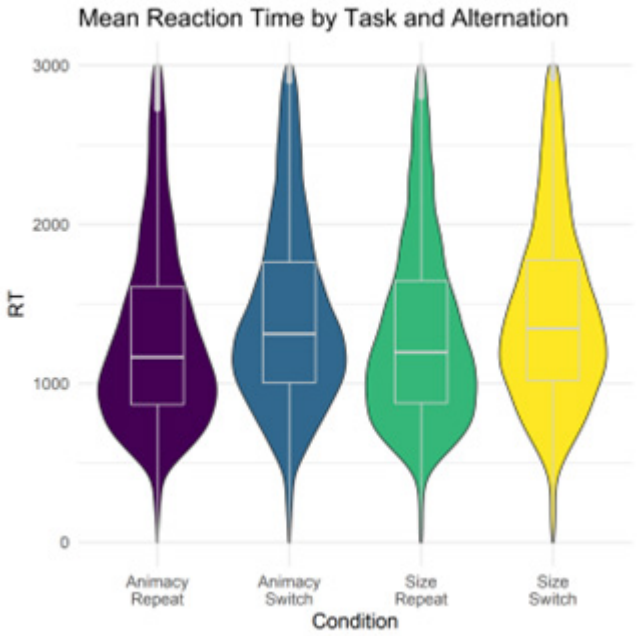

Figure 3*: Mean Reaction Time by Task and Alternation*

Table 1*: log10(RT) ~ task * alt * platform + (1 | participant)*

Effect	df	F	p-value
Task	1, 68513.88	73.87 ***	<.001
Alt	1, 68512.14	947.07 ***	<.001
Platform	1, 252.97	20.83 ***	<.001
Task:alt	1, 68512.71	2.69	.101
Task:platform	1, 68513.88	22.05 ***	<.001
Alt:platform	1, 68512.14	40.16 ***	<.001
Task:alt:platform	1, 68512.71	0.94	.331
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 ' ' 1			

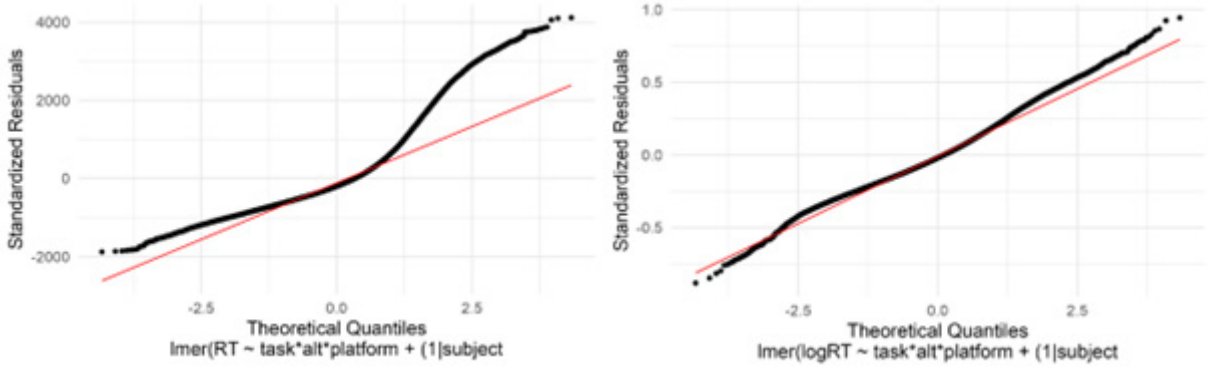

Figure 4*: Standardized Residuals by Theoretical Quantities (LEFT); Standardized Residuals by Theoretical Quantities LogRT (RIGHT)*

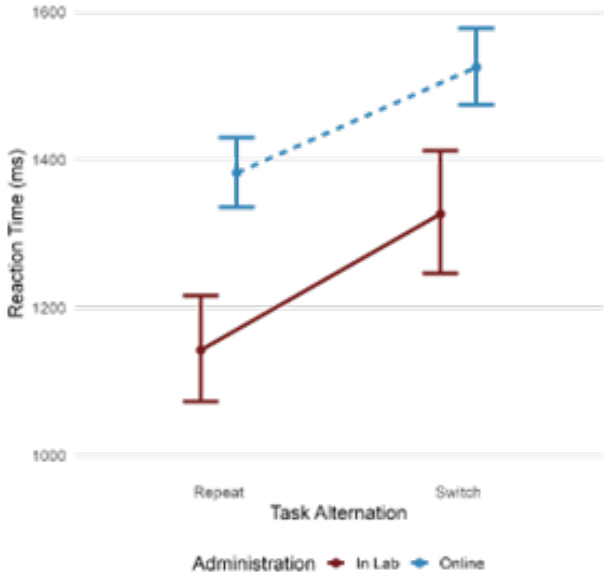

Figure 5: *Reaction Time by Alternation and Administration*

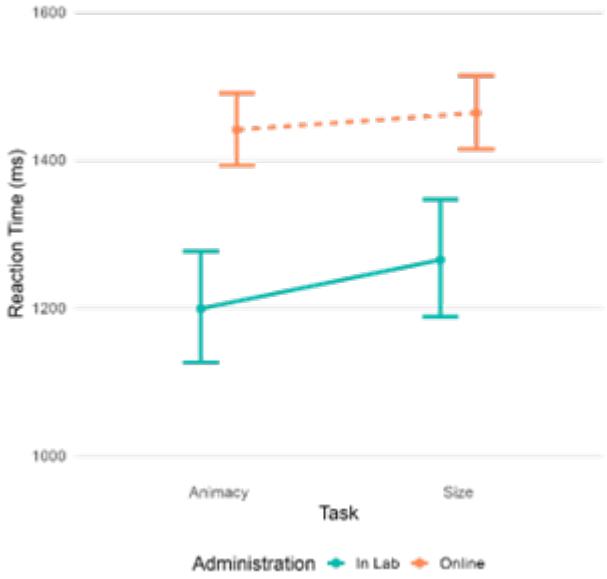

Figure 6: *Reaction Time by Task/Block Type and Administration*

unexplained variance. The larger the value, the larger the variation is than the expected normal variance. All effects are significant except "task:alt" and "task:alt:platform."

A QQ-plot (**Figure 4**) showed that the data distribution was abnormal because reaction time tends to be highly skewed. Therefore, reaction times were log-transformed, resulting in a better distribution.

The effect of administration and task alternation by reaction time was observed (**Figure 5**). Repeat tasks have faster reaction time than switch tasks. Furthermore, reaction time in the lab is faster than online. The fastest trial type was repeat tasks in the lab. All pairwise comparisons, except In Lab Switch vs. Online Repeat, are significant.

The effect of administration and block type by reaction time was observed (**Figure 6**). Reaction times for in-lab administration are faster than for online administration. In addition, animacy tasks are slightly faster than size tasks. All the pairwise comparisons are significant.

Testing Phase 2: Images and Words

The effects of alternation and block type on reaction time and accuracy were analyzed. For this phase, switch tasks are defined as participants changing from

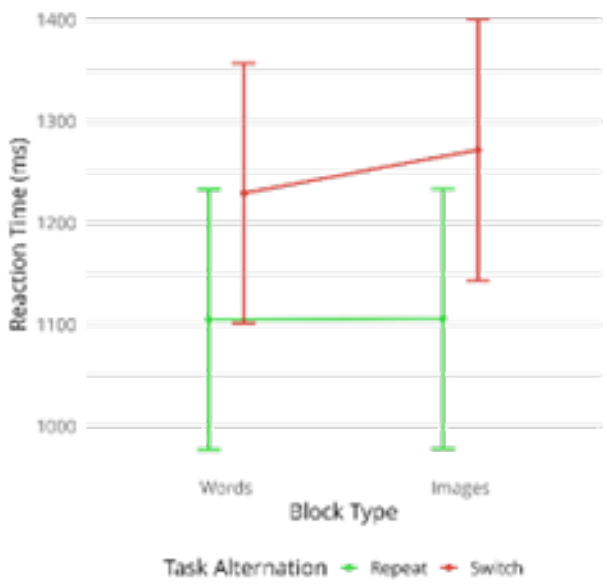

Figure 7: *Reaction Time by Block Type and Task Alternation*

categorizing the image/word based on animacy to size or vice versa. With repeat tasks, participants continue categorizing the image/word in the same category. When comparing switch and repeat tasks (**Figure 7**), there was a longer reaction time for switch tasks overall. Furthermore, switch tasks based on image blocks had the highest reaction time, which shows participants took longer to process these tasks.

Table 2: *RT ~ blockType * alt + (1 | participant)*

Effect	df	F	p-value
blockType	1, 3872.42	1.18	.277
Alt	1, 3872.83	52.74 ***	<.001
blockType:alt	1, 3873.05	1.09	.296
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 '' 1			

Table 3: *acc ~ blockType * alt + (1 | participant)*

Effect	df	Chisq	p-value
blockType	1	11.34***	<.001
Alt	1	2.01	.157
blockType:alt	1	0.98	.323
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+' 0.1 '' 1			

A linear mixed model ANOVA test was conducted (**Table 2**). The ANOVA was a type 3 test using the Satterthwaite method. A linear mixed model is useful for calculating reaction time for continuous variables like reaction time. Overall, the alternation effect is significant.

A generalized linear mixed model ANOVA test was conducted (**Table 3**). A linear mixed model was used because accuracy is not a continuous variable. The ANOVA was a type 3 test with the likelihood ratio test (LRT). The LRT test conducts a likelihood ratio test between two model fits. Afterward, it determines which model is more complete by comparing the model components. Because of this method, a chi-square distribution as the standard test was conducted. A linear mixed model was used to calculate reaction time, which is helpful for continuous variables. Overall, only the condition effect is significant.

The effect of block type by alternation was compared (**Table 4**). The z-ratio calculated the difference in low-frequency power to high-frequency power in relation to total available power. Based on the graph, all contrasts are statistically significant except "repeat image - repeat word" and "switch image - switch word." The Tukey method calculates the p-value, allowing us to compare a family of four estimates.

Table 4: *Block Type by Alternation*

Contrast	Estimate	SE	Df	z-ratio	p-value
repeat image - switch image	-166.118	28.3	Inf	-5.877	<.0001
repeat image - repeat word	0.799	28.0	Inf	0.029	1.0000
repeat image - switch word	-123.526	27.9	Inf	-4.429	0.0001
switch image - repeat word	166.917	28.6	Inf	5.832	<.0001
switch image - switch word	42.592	28.5	Inf	1.496	0.4400
repeat word - switch word	-124.325	28.3	Inf	-4.393	0.0001

> **FUTURE USES OF NATURALISTIC STIMULI CAN AID IN UNDERSTANDING COGNITIVE MAPS WITH SPATIAL NAVIGATION**

CONCLUSION

We discovered how naturalistic stimuli relate to animacy and size regarding reaction time, alternation type, administration, and accuracy. From phase one, we found participants had a longer reaction time with switch tasks. Our findings further support research regarding switch and repeat tasks.[10] From phase two, while participants took longer to categorize images, they also had a higher accuracy with image-based stimuli. This time difference is shown by the overall switch cost reliability (0.26), switch cost for images (0.40), and switch cost for words (0.05). Finally, we analyzed the conditional and marginal R^2 values for word data (0.182 and 0.01) and image data (0.20 and 0.01). Marginal R^2 values report variance explained by fixed factors, while conditional R^2 values report variance explained by both fixed and random factors.[13]

Understanding the importance of naturalistic stimuli can have many effects throughout psychology and clinical settings. It can help reduce the replication crisis in psychology by providing transparent and honest results. By exploring new forms of stimuli, we can improve the narrow usage of simple stimuli in current literature. In addition, future uses of naturalistic stimuli can aid in understanding cognitive maps with spatial navigation and disorders with social interactions.[14] Overall, naturalistic stimuli can open new doors for research and exploration. Future directions for this study would be to update our dataset using more reliable images and words. In addition, the study could be sent to neuroscience studies for more reliable outcomes.

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Mastering the Surgeon's Touch: 3D Printing for Cardiac Surgical Training

By Ananya Joshi '25

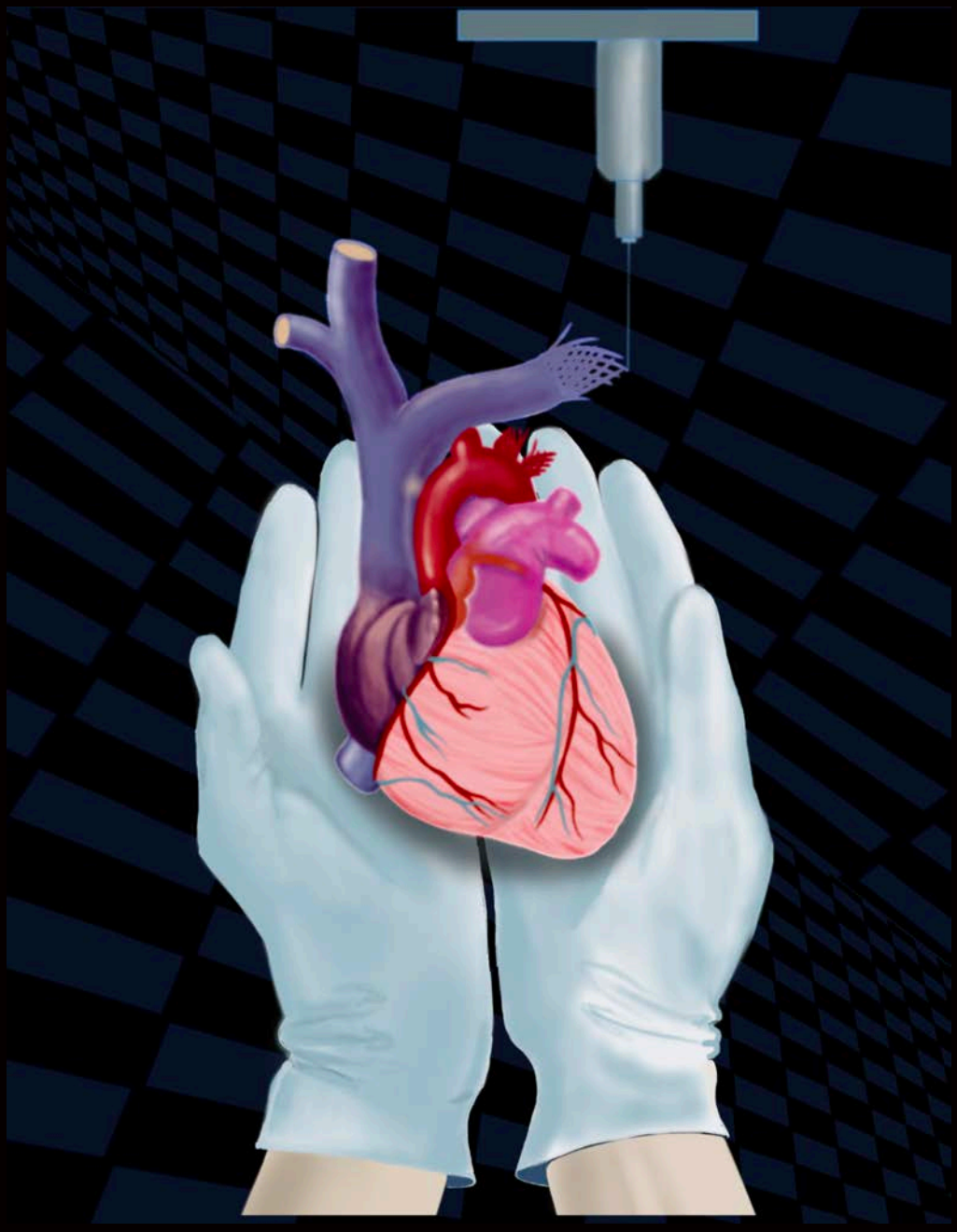

Image Credit: Ananya Joshi

INTRODUCTION

My artwork, *Mastering the Surgeon's Touch: 3D Printing for Cardiac Surgical Training,* intricately intertwines three individual elements to form a cohesive and meaningful piece. Through the imagery of the heart, gloved hands, and 3D printer, it explores the themes of medical innovation, the fragility of life, and the essential role of skilled surgeons.

Furthermore, incorporating elements of 3D printing brings attention to the potential of this specific technology in revolutionizing surgical training. It suggests a future where medical professionals can practice and perfect their techniques on more realistic models before performing actual surgeries, thus improving patient outcomes and reducing the risks associated with complex procedures.

METHODS

This artwork was meticulously drafted on the digital platform Procreate on an Apple iPad using an Apple Pencil. The digital medium was chosen due to its flexibility and ease of editing, allowing for continuous refinement and the ability to easily add or remove elements as seen fit.

Each component of the piece was designed individually and then assembled to create a sense of layering and depth in the final piece. This allowed for multiple compositions, or arrangements of elements, to be tested before choosing the best and most relevant design. The relationship between the various elements is heavily dependent on the overall composition of the artwork; these elements must be balanced while noting the relative sizes, placement, shape, color, perceived texture, and other attributes.[1] This method ensures that every element contributes to the overall harmony of the artwork and creates balance that is pleasing to the eye.

The Heart

Upon reading the abstract for the article, "Advancing Cardiac Surgical Training with 3D Printed Tissues," my first thought was to recreate an anatomically accurate cardiac model. This led to the creation of the central element of this piece, a heart, which is the core component of the cardiac system. This cardiac muscle is approximately the size of a person's fist, so it differs between different people. As the final piece was going to include both hands and the heart, this size comparison was kept in mind.[2]

When sketching this element, references were drawn from informational sources online, such as the one shown below (**Figure 1**), to ensure accuracy and relevance. This anatomical precision makes the heart in the final piece a familiar image for those who recognize it from medical and anatomical textbooks or other educational materials.

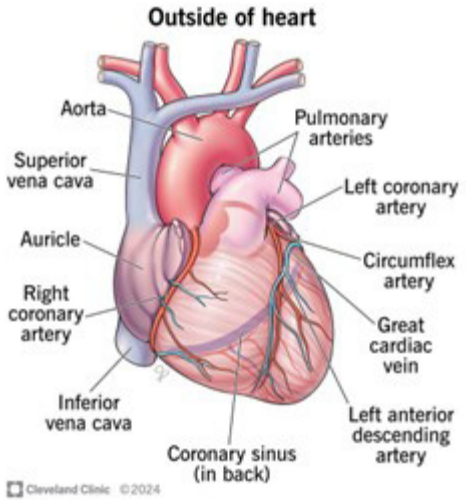

Figure 1. *Heart Anatomy and Function*

The Hands

Balanced delicately atop two gloved hands, the heart's precarious position emphasizes fragility and the precision required in surgical procedures, particularly invasive cardiac surgeries. The hands,

> **THE ARTWORK SHOULD BE INTERPRETED... AS A CELEBRATION OF THE ONGOING ADVANCEMENTS IN MEDICAL TECHNOLOGY**

encased in light blue surgical gloves, represent the skillful and practiced touch of surgeons. These gloves are a universally recognized symbol of this medical profession, accentuating the preparedness of the sterile environments where such life-saving procedures occur.

The surgical gloves on the hands are inspired by those I have personally used in a research lab, and they reflect the typical color and style of disposable nitrile gloves commonly associated with surgery and the medical field. This personal touch adds a layer of authenticity and relatability to the artwork.

The Printer

In the top right corner, the tip of the 3D printer is depicted dispensing a thread of plastic, actively generating a section of the heart. This subtle yet significant detail is intentionally placed slightly in the background. By doing so, the viewer's attention is initially drawn to the heart and hands, highlighting the critical nature of surgical intervention and the well-practiced surgeons involved. Subsequently, the viewer's gaze shifts to the 3D printer, which represents the cutting-edge technology that supports and enhances modern medical training that allows surgeons to perform these procedures.

RESULTS

The artwork should be interpreted by the target audience as a celebration of the ongoing advancements in medical technology. For medical professionals and trainees, it serves as a reminder of the importance of pushing for further technological innovations that can improve their practice. It also encourages them to think creatively about how these technologies can be applied in their own work. For enthusiasts of medical technology, the artwork offers a glimpse into the future of healthcare, where cutting-edge tools and techniques play a crucial role in patient care and surgical success.

Furthermore, the 3D printer's role in the artwork symbolizes the integration of new technologies into surgical training. This aspect is particularly relevant in the context of cardiac surgery, where precision and effective training are paramount. The unfinished edges of the heart convey the message that surgical skills and technologies are constantly evolving, driven by the need for more effective and safer medical procedures.

The delicate interaction between the hands, the incomplete heart, and the 3D printer is a deliberate choice to illustrate the symbiotic relationship between human skill and technological innovation in the field of cardiac surgery. The gloved hands, steady and skilled, reflect the expertise required to perform intricate surgeries, while the heart, still in the process of being printed, signifies continuous advancement and the potential for future developments in the medical and surgical field.

CONCLUSION

The primary role of this cover artwork for *Explorations* is to create a visual bridge between technological advancements, such as 3D printing, and their applications in healthcare and education. The depiction of the mid-print heart being precariously

balanced on the gloved hands serves as a metaphor for the precision and care required in both medical practice and technological innovation. By showcasing this intersection, the artwork encourages viewers to consider how 3D printing can create detailed, accurate replicas of organ tissues, providing invaluable resources for training and research.

My artwork, inspired by the concept of advancing cardiac surgical training with 3D printed tissues, aims to portray a cardiac model created by relevant printing technology being used for surgical training. It situates itself at the intersection of art, technology, and medical science, highlighting the innovative methods being developed to improve surgical outcomes and training efficiency. By encouraging viewers to think about the future use of technologies such as 3D printing in healthcare and education, the artwork draws attention to the ongoing growth and potential in these fields. It invites the target audience to reflect on the transformative impact of technology on medical practice and to appreciate the continuous journey towards better medical outcomes.

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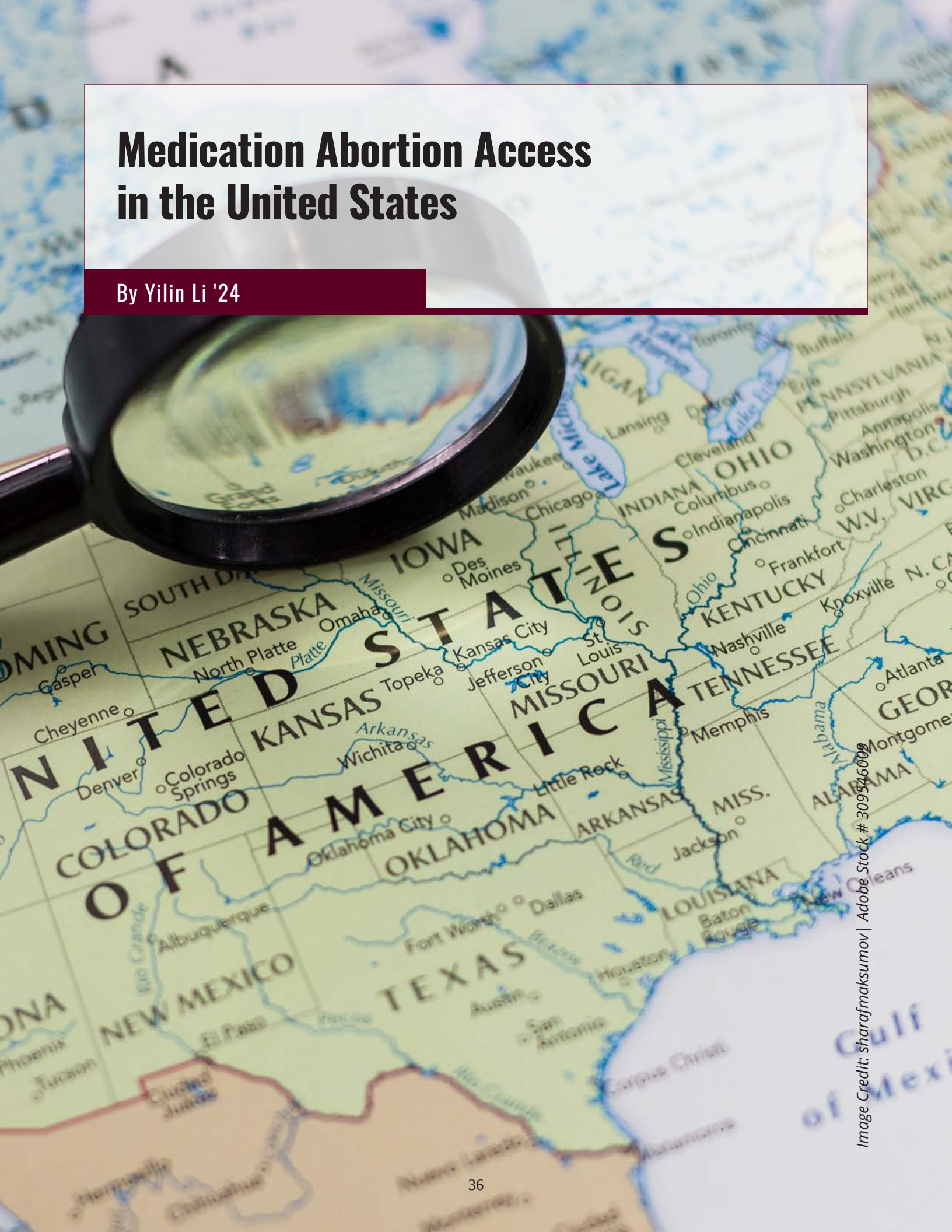
Medication Abortion Access in the United States

By Yilin Li '24



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INTRODUCTION

Since the United States was founded, abortion access has fluctuated between periods of increased access and tightening restrictions. Prior to the 1800s, laws did not restrict access to abortion. However, in the 1900s, a coalition of male doctors and the Catholic Church led a movement to push state governments to outlaw abortions.[1] By 1910, abortion was banned nationwide. In the 1960s, alongside the Civil Rights movement, restrictions on abortion access began to loosen. These bans culminated in 1973 with the Supreme Court enshrining the legal right to access abortion in *Roe v. Wade*.[2] However, in the 2000s and 2010s, a new movement began to tighten restrictions at the state level. *Roe v. Wade* was overturned in 2022 by *Dobbs v. Jackson*, which led to many states banning abortion access. At the time this article was written, abortion access in the South is inaccessible from El Paso, Texas to Williamsport, West Virginia. Without any national legal statute ensuring abortion rights, access is declining in many states, alongside general reproductive care.

Abortion is a commonly debated election issue, but it is undeniable how many individuals it impacts. One in five pregnancies ends in abortion, and more than half of abortions are medication abortions. The Supreme Court will hear cases on medication abortion access in spring 2024 and issue a formal ruling in summer 2024. To understand the effect of this potential ruling, I am studying the 2023 Food and Drug Administration (FDA) deregulation of the options individuals have in accessing medication abortions. My paper finds that counties with increased access through mail-in and licensed pharmacy access lead to fewer physical trips taken in each county. Current literature has only studied general abortion access and used only abortion counts reported by the government. My paper will contribute by factoring in new changes to the abortion landscape: increased medication abortion usage, non-formal medication access, and states halting abortion count collection.

Abortion is a medical procedure that eliminates a pregnancy. This termination can occur in two forms: surgical abortion and medication abortion. Surgical abortions are a medical procedure where suction empties a woman's uterus. Medication abortion, popularized in the last two decades, consists of using two different medications, mifepristone and misoprostol. Medication abortions are frequently used for pregnancies under 11 weeks in gestation. It is effective at terminating a pregnancy 99.6 percent of the time, with a mortality rate less than 0.001 percent.[3]

Like surgical abortions, the federal government and state governments have wrestled with medication abortion access. The FDA approved mifepristone in 2000. The original approval allowed usage through seven weeks gestation. In 2016, the FDA extended usage of mifepristone to 10 weeks gestation. More recently, the FDA approved a rule change in January 2023 that allows more retail pharmacies and mail-order companies to dispense mifepristone pills. After *Dobbs v. Jackson* was overturned, abortion pills became debated in the courts. On April 7, 2023, two U.S. District judges, one in Texas and one in Washington state, issued opposing rulings on the FDA's original approval of mifepristone. In response, the Supreme Court placed the two lower court decisions on hold, agreed to review the case in spring 2024, and will likely release a decision by late June. The decision the Supreme Court makes will have consequential effects on abortion access.

Abortion access has been studied separately by economists and public health researchers. I aim to combine both aspects, as it is worthwhile to use the economics models and include public health researchers' nuanced understanding of the abortion landscape.

Understandably, the distance to the nearest abortion clinic affects abortion access. Current economics literature analyzes Texas. Furthermore, it also projects *Dobbs v. Jackson*'s effects to understand how the abortion landscape will change after the historic decision. Starting with Texas, Lindo et al. (2020) studied TRAP, Targeted Restrictions on Abortion Providers, laws that were passed in 2013. The new regulations required physicians at abortion clinics to have admitting privileges in a hospital within 30 miles of the clinic, forcing many clinics in Texas to close.[6] Due to these closures, Lindo finds that an increase in distance by 100 miles reduced abortion rates by 22 percent, and increases in distance have less effect in counties that were already over 200 miles away from

abortion clinics. Additionally, Myers (2023) studies the effect of changes in distance across America after *Dobbs v. Jackson* shuttered abortion clinics. By using a continuous staggered treatment analysis, she estimates that an increase from 0 to 100 miles will reduce abortions by 19.4 percent and increase birth rates by 2.2 percent.[7]

This distance and appointment unavailability forces individuals seeking an abortion to turn to other methods, especially if their pregnancy is still under 10 weeks. For example, the purchasing of medications from international sources, which circumvents laws, has skyrocketed. This increased demand occurs especially in states with tighter restrictions. Aiken et al. (2021) find that at the county level, increased distance to an abortion provider is associated with an increased demand for Aid Access services. Between 2018 and 2020, over 57,000 people in 2,400 counties in all 50 states requested self-managed medication abortions. Commonly cited reasons for medication abortion were privacy, cited in 49 percent of requests, and clinic distance, cited in 40 percent of requests.[8] Aiken et al. (2022) studied the effect of *Dobbs v. Jackson*'s initial leaking and formal ruling on requests for medication abortion. The telemedicine service Aid Access recorded these requests, amounting to over 40,000 in 30 states. Regardless of state abortion policy, there was a higher rate of requests after the leak and after the formal decision was announced. States with a total abortion ban, mostly located in the South, had the largest increases in requests.[9]

The current literature lacks a study that captures the abortion landscape using econometric techniques with these public health nuances. It does not distinguish between medication and surgical abortions, which is relevant because both are regulated separately. Additionally, data that tracks legal abortions in America fails to account for other methods that circumvent abortion methods. This includes traveling or purchasing pills from another country. However, public health research conducted in Aiken et al. (2021) and Aiken et al. (2022) begins an interesting discussion on how the landscape is changing with more requests for medication abortion in states with bans. This paper also focuses on this change, understanding how telemedicine and abortion pills have changed the effect of distance on abortions. I will incorporate post-pandemic and post-Dobbs data as pandemic recovery and Dobbs restrictions occurred in the same time period. Myers (2023) reports that only 33 of 48 continental states report county-level abortion counts. Since I want to include all counties in the United States, I use an instrumental variable of trips which serves as a proxy for abortions.

METHODS

To measure how far individuals are from abortion clinics in the United States, I am using data collected by Dr. Caitlin Myers at Middlebury College. In the Myers Abortion Facility Database, Dr. Myers compiled a list of abortion providers that advertised their services online.[10] Then, using HERE API, a STATA georoute module, Myers identifies the nearest facility by travel distance from each county. The data is collected monthly for each county from 2009 to 2023. It also contains the number of facilities in the destination county, along with the population of women in the origin county.

Tracking all abortions is complicated and is not collected in every U.S. state. I use a proxy for abortions, the number of trips taken in a county, to measure the number of visits to abortion clinics. The trip data is estimated for the Bureau of Transportation Statistics by the Maryland Transportation Institute and Center for Advanced Transportation Technology Laboratory at the University of Maryland. [12] It is calculated from an anonymized national sample of mobile device data. Using a weighting procedure, they expand the sample to millions of mobile devices. They define trips as "movements that include a stay of longer than 10 minutes at a location away from home." The location of the device owner's home is calculated on a weekly basis.

Both data sources have limitations, affecting the sample size and time period of analysis. As of my paper's analysis, the Myers Abortion Facility Database extends to October 2023. The Trips by Distance project began collecting data on January 1, 2019, also restricting the time period of our study. This paper uses county-level trip data; thus, it is not specific for demographic characteristics (i.e., gender, age, and race). Additionally, it is collected at the daily level, so I aggregated it to monthly levels to merge with the abortion access data. Each coun-

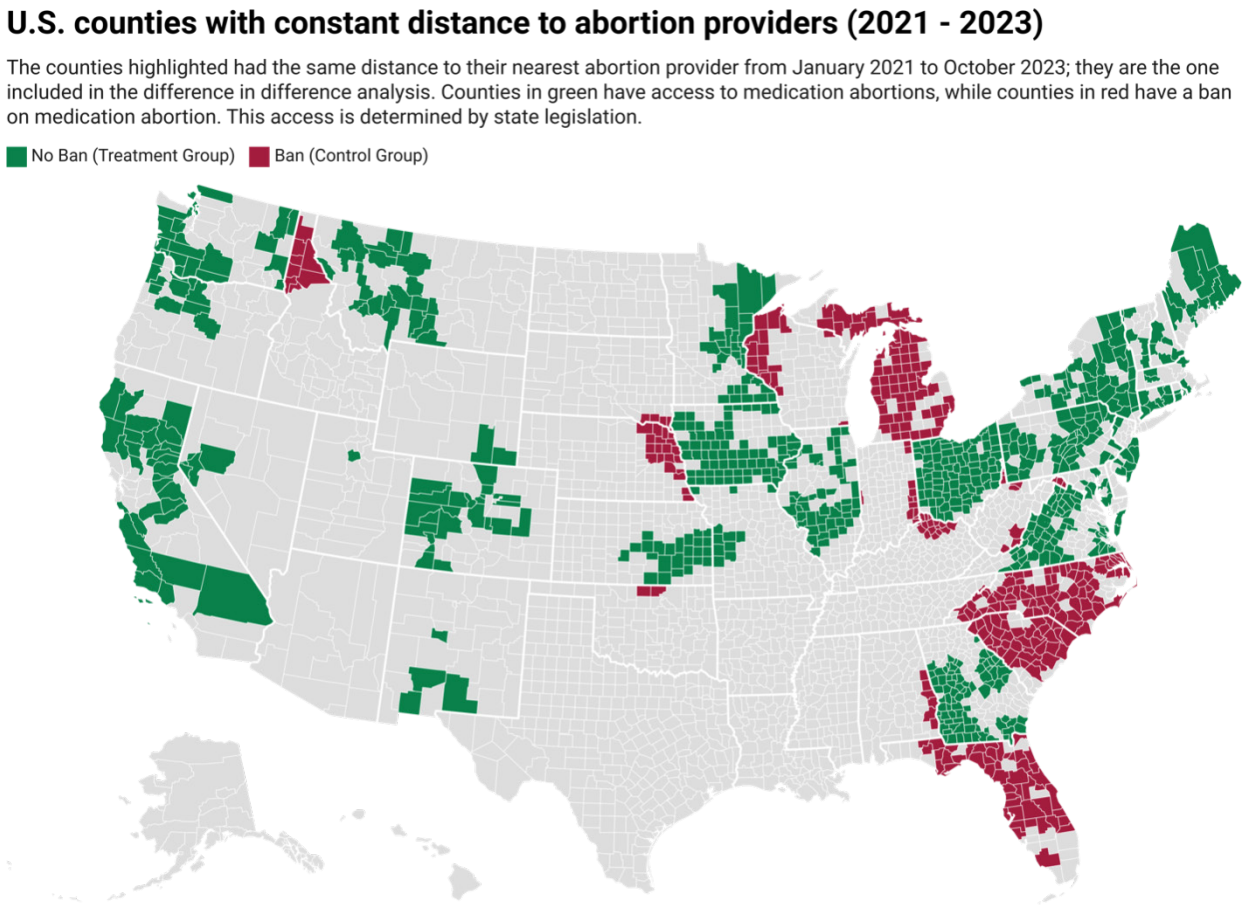

Figure 1. *Sample Counties: The map, created using Datawrapper, shows the counties included in the analysis. This was coded using data from the Guttmacher Institute, which noted which states have a near total ban on abortion access, including medication abortion. Counties in green have access to medication abortions, while counties in red do not because of state bans. Counties not highlighted, in gray, do not maintain the same distance from their nearest abortion provider in the sample time period. While I have data on all counties, I am restricted to these counties because of the difference-in-differences model I chose to run. I also restricted my analysis from January 2021 through October 2023, while I do have data starting in January 2019.*

ty-by-month observation in the trip data has multiple categories of trip distance. They report the total number of trips taken that month and the number of trips taken in distance categories: 1 to 5 miles, 5 to 10 miles, 10 to 25 miles, 25 to 50 miles, 50 to 100 miles, 100 to 250 miles, 250 to 500 miles, and above 500 miles.

To measure the effect of the FDA's 2023 deregulation on trips to the abortion clinic, I use a difference-in-differences econometric technique. Difference in differences, DID, studies the difference in effect of the treatment, comparing the treatment group to a control group. The treatment effect is calculated by subtracting the average change in the outcome for the treatment group from the average change from the control group. It allows researchers to argue for causality, as the model mimics a natural experiment. However, the DID relies on the two groups to be identical, a parallel trends assumption. The selection of the treated and control groups is important. If the two groups are not identical, then the outcome is not causal to the treatment, which is known as an omitted variable bias. Or, the model will fail because of reverse causality, where the outcome determines the selection of the groups.

The difference-in-differences model I conduct measures the effect of FDA medication abortion deregulation on trips taken to the clinic in January 2023. This deregulation only affected states where medication abortion is legal, creating the treatment group. Our control group is counties in states where medication abortion access is banned. To ensure parallel trends, I only analyze

counties that maintain the same distance from their nearest abortion clinic from January 2021 to October 2023. Thus, the control and treatment counties have similar incentives or disincentives to travel to their abortion clinic over the entire time period.

I conducted this analysis on counties that were within 5 to 100 miles of their nearest abortion clinic for the entire time period. I cut the sample this way because I believe counties that are less than five miles away from their nearest abortion provider are close enough that FDA deregulation to increase access does not affect them. In addition, I believe counties over 100 miles are too far from their nearest abortion provider, so they are already disincentivized to get an abortion. For robustness checks, I also ran it for separate distance groups, 5 to 10 miles, 10 to 25 miles, 25 to 50 miles, and 50 to 100 miles.

$$\text{Trips} = \beta_1 * \text{Treatment} + \beta_2 * \text{Post FDA Expansion} + \beta_3 * (\text{Treatment X Post FDA Expansion})$$

Equation 1. *Difference-in-differences equation*

RESULTS

The columns in **Table 1** below have different coefficients. Column 1 includes the entire sample, while columns 2 through 5 examine effects for different distance categories. Most of the columns have negative coefficients, which indicate FDA rule change treatment leads to fewer trips taken. Column 1's distance range is too large; the range from 5 to 100 miles includes many counties that vary in population, size, income, demographic characteristics, etc. Lastly, column 4 and 5 both have negative coefficients, with column 4 coefficient's magnitude being larger than column 5's coefficient.

Furthermore, columns 2 and 3 are not statistically significant. Counties that are 5 to 25 miles away from their nearest provider will not be largely affected by FDA REMS rule change since the length of the trip does not deter abortions. Furthermore, there many more reasons that individuals take trips between 5 to 25 miles, making it difficult to use number of trips as a proxy for trips to an abortion clinic. This is supported by literature that suggests counties closer to clinics have higher abortion rates because of easier access. Furthermore, the dependent variable is the number of trips between 5 to 10 miles and 10 to 25 miles, which are common trip lengths. Thus, it will be difficult to isolate impacts of abortion trips as well. Column 4, which only includes counties 25 to 50 miles away, is statistically significant to the 99 percent confidence level. These counties are close enough where control counties will still make the trip to the clinic, but far enough that mail-in or licensed pharmacies are attractive options. Column 5 is also statistically significant to the 90 percent confidence level. There are two possible explanations of this significance level: the increased

	(1)	(2)	(3)	(4)	(5)
Distance Category	5-100 mi	5-10 mi	10-25 mi	25-50 mi	50-100 mi
FDA Deregulation	-605.8	-17229.7	134.8	-888.6***	-156.7*
	(2670.4)	(13529.6)	(3238.0)	(342.4)	(91.3)
Observations	33,785	3,128	5,032	11,152	14,473

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1. *Difference-in-differences Results: This table demonstrates the difference-in-differences results in different distance groups analysis. The fourth column demonstrates that after the FDA rule change went into effect in January 2023, the control group continued taking similar levels of 25 to 50 miles trips, while the treated group declined.*

number of counties included and the decrease in number of trips generally taken from 50 to 100 miles.

Column 4 is the ideal result of a difference-in-differences model. As seen in **Figure 2**, the treated and control groups have identical linear trends. This gives confidence that the counterfactual is a good comparison for how the treatment group would have trended, supporting causality. After the FDA rule change went into effect in January 2023, the control group continued taking similar levels of 25 to 50 miles trips, while the treated group declined. Since the data is not specific to trips to abortion clinics, this does not translate to 888 fewer physical abortion visits for each county and month. However, the parallel trends and negative coefficient with significant magnitude does demonstrate some effect of the FDA REMS rule change in 2023.

CONCLUSION

As the nation has seen after *Dobbs v. Jackson*, the federal government's power over abortion access is restricted. The FDA and its role in exacerbating the differences between states' abortion access lends to an interesting model. Furthermore, medication abortion is increasingly popular, and many providers offer a loophole for the current U.S. abortion landscape. These layers complicate the simple model economists have previously used.

While surgical abortions cannot be fully replaced with medication, there is needed discussion about medication abortion's role. Mail-in and pharmacy-provided medication abortion may allow more individuals to seek surgical abortion access at facilities. It also may lead to less usage of surgical abortions, granted individuals decide before 10 weeks they want to seek an abortion and have access to medication.

The Supreme Court's upcoming decisions on *Food and Drug Administration v. Alliance for Hippocratic Medicine* and *Danco Laboratories v. Alliance for Hippocratic Medicine* will have undeniably consequential impacts. Whether they decide to repeal mifepristone, or whether they strike FDA rule changes, it has the potential to affect the abor-

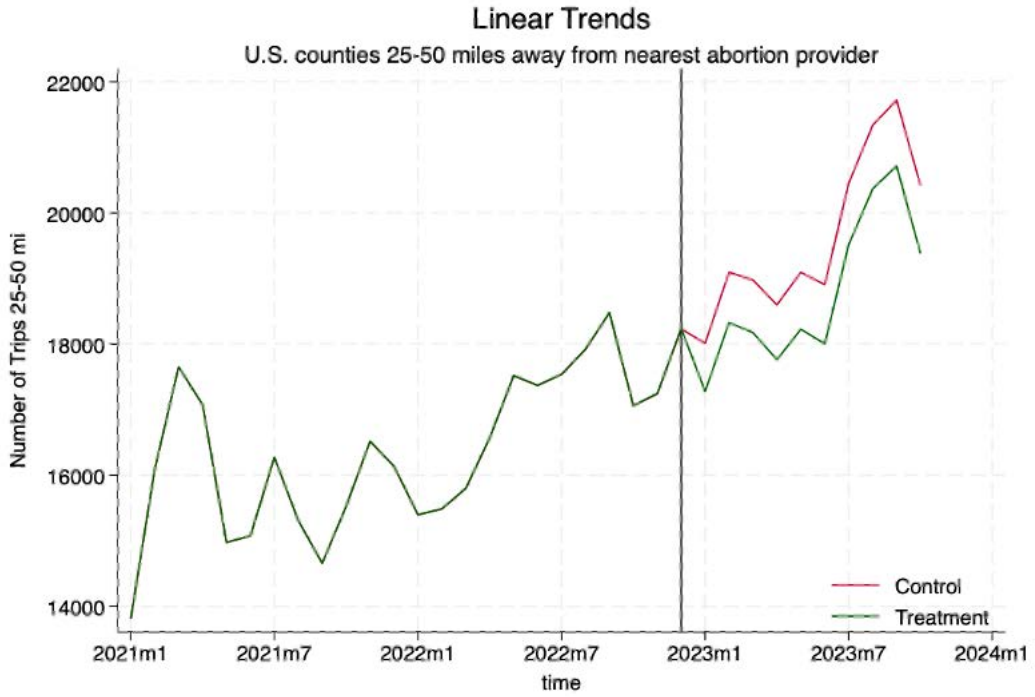

Figure 2. *Linear Trends Results: Figure 2 demonstrates the observed means of the treated and control groups, showing that the control group took more trips than the treatment. The red line represents the control counties that have no access to abortion and the green counties represent the treatment counties that are affected by FDA REMS rule changes. As seen by the black line, after the 2023 REMS rule change went into effect, the control counties took more trips in comparison to the treatment counties that continued pre-treatment trends.*

> **THROUGH ECONOMICS, PUBLIC HEALTH, OR PUBLIC POLICY LENSES, RESEARCHERS SHOULD UNDERSTAND ALL ASPECTS OF ACCESS TO HEALTHCARE**

tion landscape more than the repeal of *Roe v. Wade*.

I studied the effect of the FDA rule change in 2023 on medication abortion access, using the number of trips taken as a proxy for access. Using data from the Bureau of Transportation Statistics and Myers Abortion Facility Database, I used a difference-in-differences model. I find that treated counties between 25 to 50 miles experience a decrease in 888 trips per month after the 2023 rule change was adopted. I hypothesized that this drop in trips is due to usage of licensed pharmacies and mail in medication abortions. This result was causal, since the control and treatment groups had similar parallel trends. I hypothesized that counties with FDA access took fewer trips drop in trips because they took fewer trips to in-person abortion clinics, as individuals shifted to licensed pharmacies and mail-in medication abortions.

Overall, research on medication abortion needs to be at the forefront of abortion research and discussions. Medication abortion usage has grown immensely in the last decade, especially through non-formal healthcare providers, while research has staggered. Through economics, public health, or public policy lenses, researchers should understand all aspects of access to healthcare and work to develop models that describe the current landscape.

ACKNOWLEDGEMENTS

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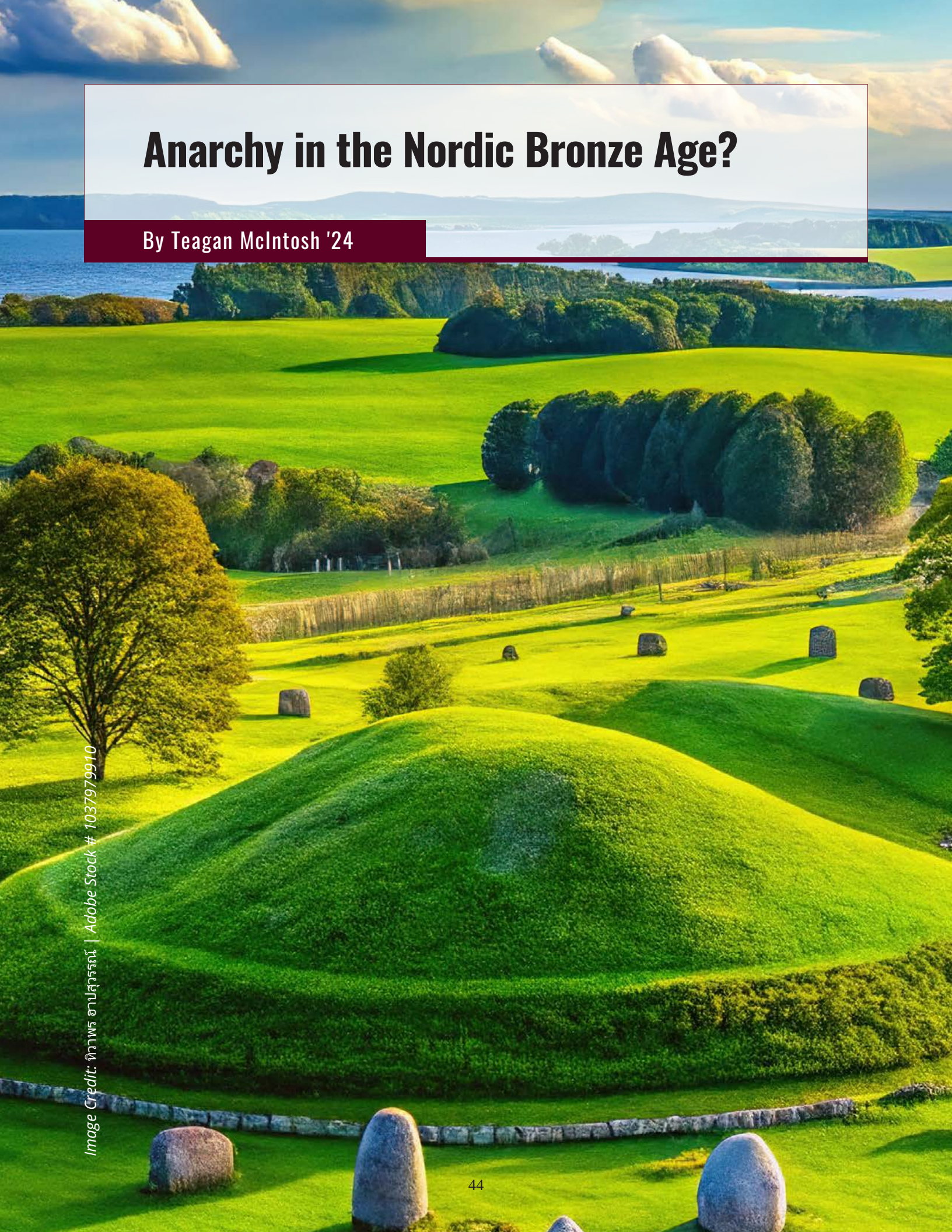
Anarchy in the Nordic Bronze Age?

By Teagan McIntosh '24



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INTRODUCTION

The Nordic Bronze Age started circa 2000–1700 BCE[1] and ended in 500 BCE with the introduction of the Iron Age.[2] The nature of the sociopolitical organization of the Nordic Bronze Age is an area of uncertainty among archaeologists. Chiefdoms are similar to kingdoms in that they are hierarchically organized based on kinship, with a governing power that is central to society. However, the scale of control for a chiefdom is smaller than that of a kingdom, with populations ranging in the thousands compared to hundreds of thousands.[3] While some authors argue that Scandinavian society consisted of centralized chiefdoms with a warrior ideology, others believe that forms of egalitarian politics and organization were more common. These differences in opinion stem from varied sources and different interpretations used by researchers. For instance, while burials reveal a stratified chiefdom, settlement patterns suggest a more equal society. Resource availability also varied widely over the 1,500-year period of the Nordic Bronze Age. By comparing Early and Late Bronze Age burials and settlements through an anarchic perspective, we can see that individual autonomy and decentralized power were not uncommon in Scandinavian society. In this study, "anarchy" does not refer to a lack of order but rather to alternative views of how societies organize outside of hierarchical formations and how they actively resist forms of domination, inequality, and centralized control over power and resources while promoting equitable and voluntary association.[4]

MEANINGS AND INTERPRETATIONS OF EARLY BRONZE AGE BURIAL MOUNDS

Burial structures and ritual practices can inform archaeologists about the organization of a past society, their beliefs, and what they held as culturally significant. The construction of monumental burial mounds and the wealth of grave goods found indicate that these burial mounds (barrows) belonged to the elites of society. Kristiansen[5] calculates that out of approximately 50,000 barrows associated with the Early Bronze Age (EBA) in Denmark, only 20 percent of the adult population who were estimated to have died during Period II and III (1500–1100 BCE) were interred in burial mounds. This small proportion of the total population buried indicates the presence of a small, elite group derived from chiefly lineages.

While the barrows of the Early Nordic Bronze Age seem to be associated with the elites of society, Kristiansen[6] argues for a ranked elite class due to variations in the size of burial mounds, with small mounds representing a lower rank of elites that were close in status to commoners. Despite his claims, other authors, including Levy[7] and Johansen, Laursen, and Holst,[8] state that there seems to be no discernible difference or correlation between the wealth of grave goods and that of mound size, with few exceptions. Tornberg's[9] analysis of cavities in Scania, located in southern Sweden, also suggests a lack of differentiation between grave types across social classes, indicating no difference in dietary consumption between statuses. Although there is regional variation, this trend can be observed in the broader interpretation of Scandinavian society. This is supported by the studies of EBA barrows in Denmark by Johansen, Laursen, and Holst,[10] which argue that there is unclear differentiation in grave goods found between barrows and other forms of inhumation.

Another possible reason for the difference in mound size could be due to the lack of resources available during construction. For an average mound of

> "BY ALLOWING MULTIPLE ELITES TO HAVE EQUAL AUTHORITY, THE CENTRALITY OF POWER BETWEEN A SELECT FEW CAN BE OPPOSED, AS SEEN IN ANARCHIC SOCIETIES"

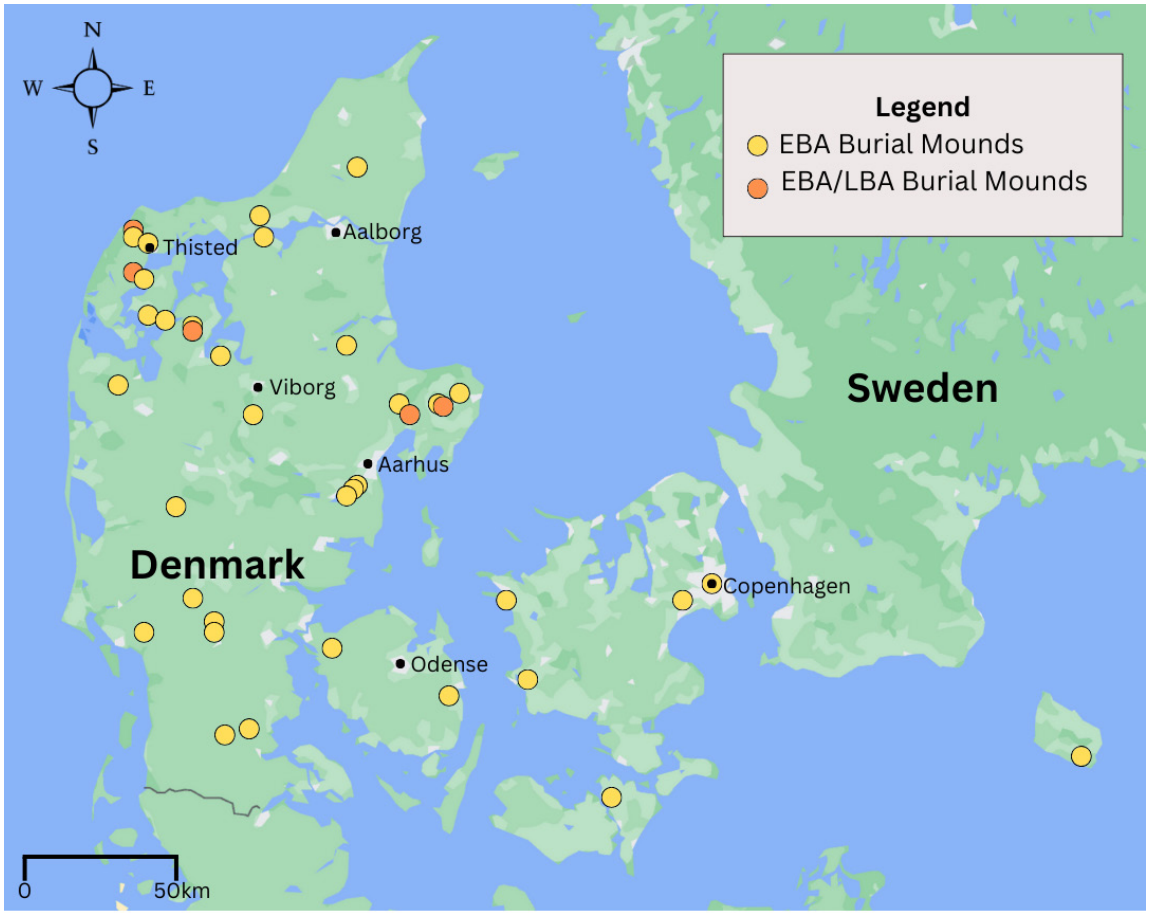

Figure 1. *Locations of Early Bronze Age burials in Denmark. Data was acquired from the Finds and Memories of the Past database from The Palaces and Culture Agency.*

two to four meters in height, it would be necessary to cut two to three hectares of grazing land to construct the burial mounds. Kristiansen[11] also notes that burial mounds were constructed frequently, with Holst et al.[12] estimating that 150 new barrows were built annually. With the reduction of grazing land and other available resources, it is possible that smaller mounds may not equate to lower-ranked chiefly elites but rather a conscious decision based on available resources.

From an anarchic perspective, the relatively even distribution of wealth in terms of grave goods and dietary consumption can indicate a decentralized elite. This decentralized elite creates a sense of equality, allowing for the reorganization of power structures in a multivocal and highly competitive setting. By allowing multiple elites to have equal authority, the centrality of power between a select few can be opposed, as seen in anarchic societies.

NETWORKS AND THE COLLECTIVE ORGANIZATION OF BARROWS

According to a study by Johansen, Laursen, and Holst,[13] the burial mounds in Denmark exhibit a linear pattern that may indicate a complex, networked system. They suggest that nearby small and dispersed settlements may have been recruited to aid in constructing a barrow. This communal building of burial mounds indicates a fairly equal society and creates fluid central areas. The linearity of barrows described in their study can similarly be seen in **Figure 1**, which shows the mapped areas of 34 barrows dated to the EBA. A similar trend is seen in **Figure 2**, which locates 27 burials associated with the Late Bronze Age (LBA). Using anarchic theory, the networked, social building of monumental structures, like barrows, can be seen as an example of mutual aid and voluntary association, where the collective comes together in an act of social unity to benefit a neighboring settlement and

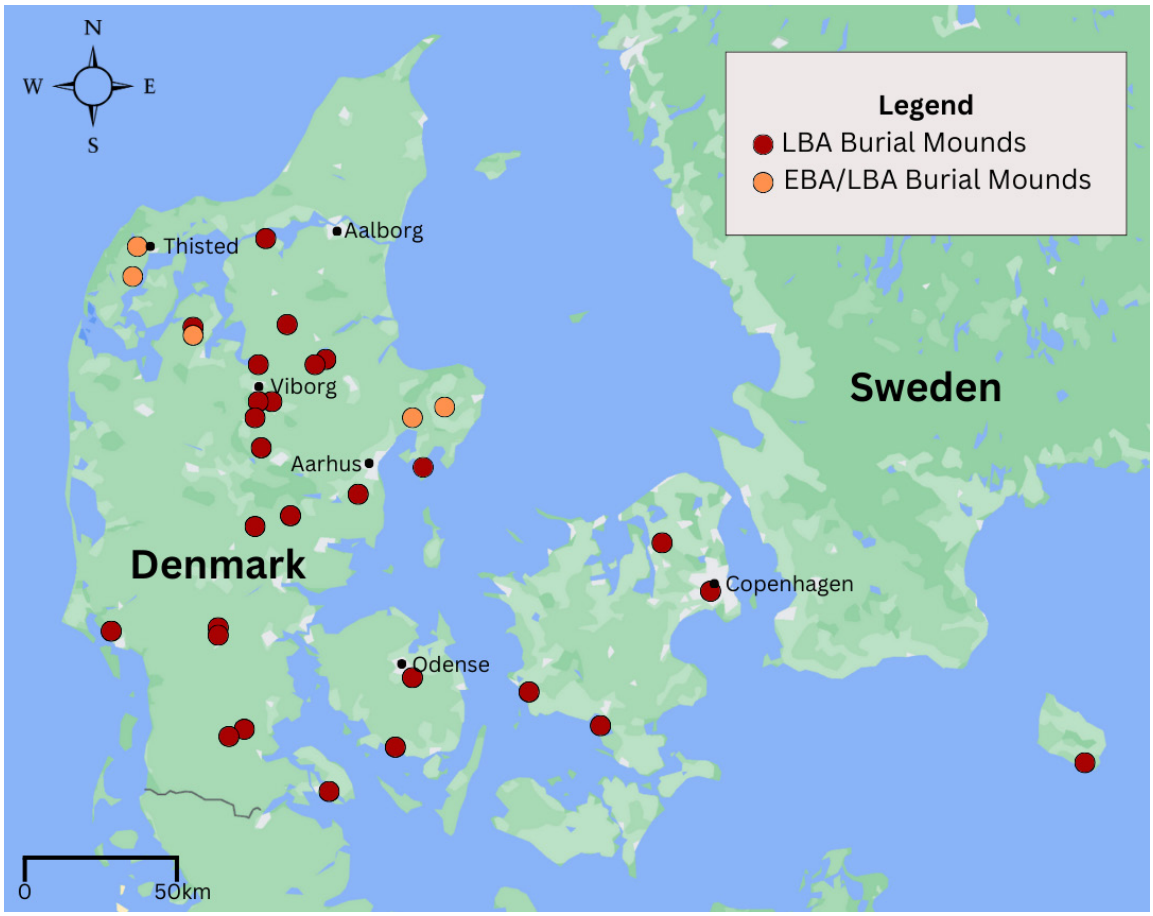

Figure 2. *Locations of Late Bronze Age burials in Denmark. Data was acquired from the Finds and Memories of the Past database from The Palaces and Culture Agency.*

strengthen relationships. The fluidity of centers where burial mounds were constructed can indicate a resistance to the centralization of barrows and ritual power and instead mark places of high social interaction.[14]

Even in monumental barrows that imply a high degree of wealth, individual autonomy and collective action are evident. Skelhøj is part of the Tobøl burial group in Southern Jutland, and is one of the largest, most well-documented burial mounds that has been excavated.[15] While the size and structure of the barrow would indicate the presence of hierarchical control, its method of construction reveals a more anarchic form of organization. The construction of Skelhøj was completed by different groups working independently on segments of the mound, as shown by variations in building practices and materials.[16] The asymmetry of the barrow also attests to independent groups of builders working autonomously but cohesively to form a larger group. Holst et al.[17] estimate that around one hundred to several hundred individuals would have participated in constructing the mound. The number of people needed to build a mound of this size far exceeds the labor available in and around local farmsteads and testifies to the networked relations settlements had. Rather than symbolizing power, mounds can be interpreted as monuments to the community; they represent collective action and mutual aid, strengthening alliances and community bonds.

LOOKING INTO LATE BRONZE AGE CREMATIONS

Barrow construction peaked in Period II (1500–1300 BCE) and began to diminish in Period III (1300–1100 BCE) until the introduction of urn burial practices in Period IV (1100–950 BCE) of the LBA.[18] The shift of burial practices to incorporate mostly cremation urn burials in the LBA could be seen as a direct response to the destruction of grazing land and surrounding forests

due to the barrows' intensive building processes and resource requirements. The change in ritual practices and methods for interring the dead, from barrows to cremation urn burials, may suggest a decrease in elite authority in the LBA. However, Reiter et al.[19] argue that while it does not equate to the effort necessary to construct a barrow, it still would be a significant effort to cremate a body, indicating that urn burials were meant for the elites. It is possible that the energy and materials saved through the adoption of urn burials could have been used to host large social gatherings for the community and maintain networks that have lasted since the construction of burial mounds.

The burials of the Nordic Bronze Age indicate a hierarchical social structure, as evidenced by the types of burials found. However, the decentralization and communal nature of the barrows indicate a more anarchic society that frequently negotiated and reorganized values and traditions. The relatively even distribution of wealth and the social spaces created by the construction of barrows suggest a more egalitarian society than previously thought.

FLUIDITY OF THE HOUSEHOLD

The household structure reflects the sociopolitical organization of Scandinavian society and reveals a competitive environment where "independent farmers, warriors, and chieftains could rise and fall in status"[20] in the frequent negotiation of power between individuals. Within this warrior society, warriors could lend their services to the households of the chiefs and participate in raids, allowing them to amass an abundance of wealth and prestige.[21] This new power and wealth could be physically represented as built extensions to longhouses. Longhouses of the Nordic Bronze Age were long, rectangular structures with two rows of roof-supporting posts, which created three aisles inside the longhouse. These structures were constructed either using a plank-built technique using timber, or with wattle and daub, combining mud and sticks to build their walls. Additions to longhouses were common and provided a larger space to accommodate more people or goods.[22] While some form of stratification was present, the ability to increase your rank within society implies that the power of the elites was limited and decentralized.

"WITH THE NEWFOUND POWER AND ACHIEVED STATUS GIVEN TO THOSE WHO SERVED THE ELITE, THESE WARRIORS COULD NOW POSSIBLY COMPETE WITH CHIEFLY HOUSEHOLDS TO BECOME CHIEFS THEMSELVES."

With the newfound power and achieved status given to those who served the elite, these warriors could now possibly compete with chiefly households to become chiefs themselves. This competition would create a cycle where chiefly households would have to acquire and appeal to more warriors to serve them, producing more competitors.[23] In this competitive environment, chiefs would need to cater to the needs of their household, or else their members could leave to serve another chief. From an anarchic perspective, the competitive environment created by this system can be viewed as an act of counterpower, where one power opposes another in a way that counterbalances each other.

Blurred societal boundaries also extend to the internal activities of the household. Some authors argue that the variation in household size indicates the presence of a hierarchy.[24] However, others argue that outside of household size, there is little evidence of social differentiation[25] and a lack of variation in activities and assemblages within households.[26] Farmsteads were largely self-sufficient in the EBA and LBA, and households practiced flexible, part-time specialization, with activities arising as opportunities occurred.[27] This is seen in Earle et al.'s[28] study of Bjerre 7 at Thy, Denmark. Despite being considered a commoner's longhouse, it had evidence of

lithic production, amber collection, and metalworking, all occurring as needed and when raw supply was available. There is also no clear correlation between craft specialization and certain households[29], while there is evidence of widespread metalworking within LBA settlements across Denmark.[30] From an anarchic perspective, the decentralization of metallurgy and open trade to non-elites demonstrates a resistance to centralized control of valuable goods and promotes equitable access to these goods to members of society.

COMMUNITY AND SHARED SPACES

Despite farmsteads' dispersed and self-sufficient nature, there seems to be a collective group identity maintained through sociopolitical networks with other settlements. It is speculated that these networks gathered the extended community for social and political events, as seen with the communal building of monumental barrows, and would help maintain relationships with neighboring settlements, which was also important for continuing trade.[31]

Social networks created between neighboring farmsteads extended to the sharing of communal grazing land. Scandinavian society practiced mixed agriculture and animal husbandry, and cattle were viewed as symbols of economic status.[32] Where arable land was present, fields for the cultivation of crops could be linked to individual farmsteads; however, the grazing lands of the heath and grasslands covered a wide landscape that connected multiple farmsteads. The extensive landscape would have been difficult to monopolize and limit access to, especially with the fluidity of settlements, allowing for grazing lands to be open to the community.[33] There is no evidence for the demarcation of communal grazing land, fences around farmsteads, or settlement fortification in the EBA. Only limited fencing is seen in the LBA, with a few exceptions, which are usually seen in hierarchical societies.[34] The absence of a central authority controlling the grazing land indicates the importance of individual autonomy within a shared space, giving each individual who uses these lands responsibility for it and consideration for their neighbors.

Shared spaces were also found inside the farmstead. While farmsteads for individual households were present, some longhouses held multiple households.[35] Legård is an EBA longhouse with evidence of two groups living at either end of the structure, as indicated by the location of the cooking pits. The living quarters on either end of the longhouse had similar structures and were of equal size. They also had equal access to the cattle stalls in the center of the house, suggesting shared cattle ownership between the two groups.[36] The large size of Legård, and the presence of cattle stalls in the middle of the longhouse, suggest that this household belonged to elite families.[37]

While settlement dispersion was normal in the Early and Late Bronze Age, towards the end of the LBA, settlement areas became more densely populated, becoming the precursor to small villages in the Iron Age.[38] This trend can be seen in **Figures 3** and **4**, where settlements from the LBA show more signs of clustering, whereas those from the EBA are more spread out across the landscape.

Despite the concentration of households in the LBA, there were landscape technologies in place to protect household autonomy and promote equality in a shared territory. According to a study published by Løvschal and Holst,[39] two major landscape technologies used to create boundaries appeared in Denmark at the end of the LBA: individual plot definition and demarcation on a landscape level. Plot definition followed the Celtic field system, extending cultivated land into heaths and forested areas. While plot size was generally influenced by the landscape and not just man, the parceling of the landscape led to the accumulation of relatively equal individual plots as smaller plots were added and larger spaces were divided. This division of land into relatively uniform pieces not only solidified group identity but also established a physical system to ensure an even distribution of land among individuals.[40] The relatively even distribution of land can be viewed from an anarchic perspective as a means to promote equality and individual autonomy while also creating physical barriers to prevent the accumulation of land by the elite members of society.

The second popular delimitation technology includes the demarcation of the landscape by pit zone alignments, mostly seen in western Denmark.

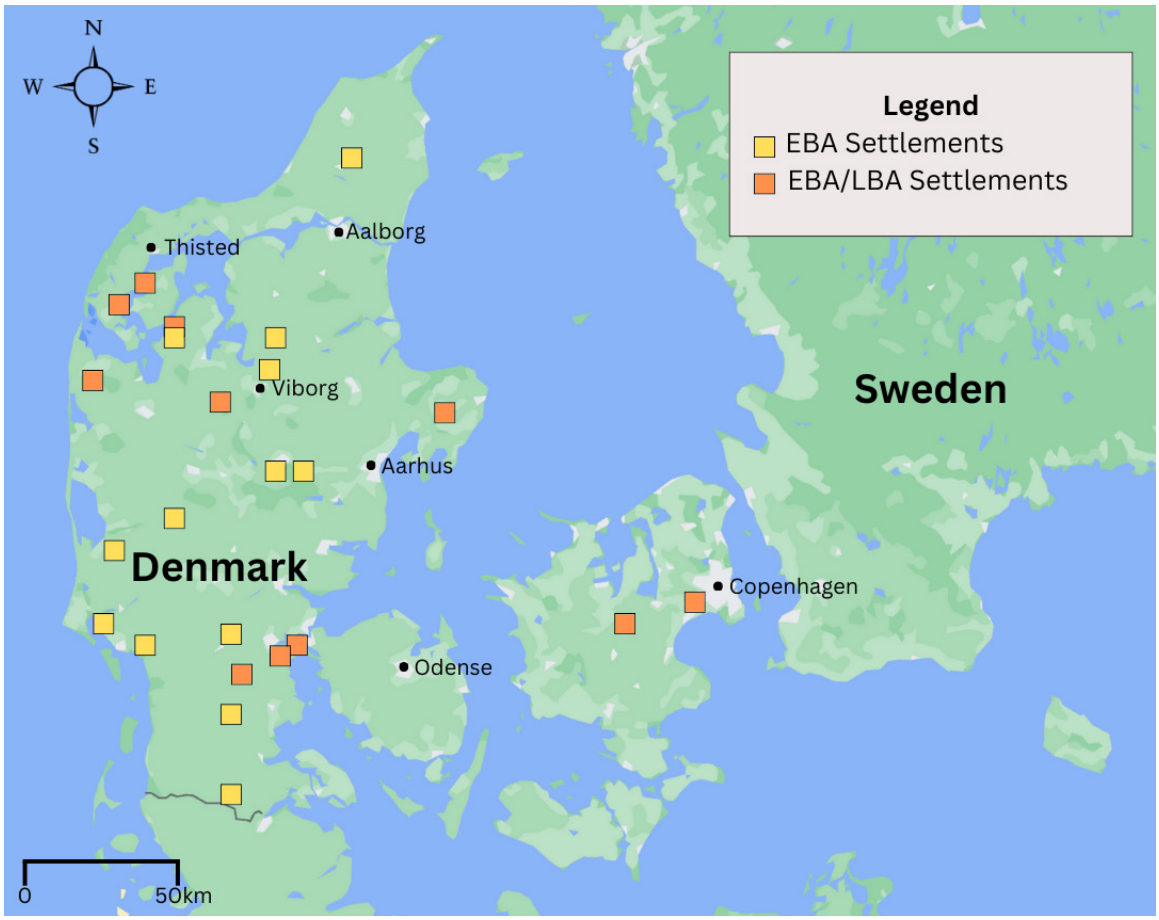

Figure 3. *Locations of Early Bronze Age settlements in Denmark. Data was acquired from the Finds and Memories of the Past database from The Palaces and Culture Agency.*

Løvschal and Holst[41] describe these pit zone alignments as "closely set open holes" that extend across the landscape for several kilometers, appearing to follow the linear barrow lines. The sizable area covered by these pit zone alignments and the absence of parceling suggests that the land was not closely tied to individual farmsteads or settlements. Instead, it appears to have been an active, communal space for many groups, similar in function to the open spaces of the EBA. Løvschal and Holst[42] argue that these pit zone alignments were likely invisible in the landscape and primarily located in transition areas between settled and unsettled regions. They likely functioned as a regulation technology to discourage individuals unfamiliar with the landscape from entering unknown areas rather than to keep certain groups of people out of the shared space.

Disagreement in the literature continues over evidence of hierarchical settlements in the Nordic Bronze Age. Some scholars believe that the size and complexity of farmsteads in the EBA show evidence of hierarchy,[43] while others argue that there is no variation within household activities or assemblages to support this.[44] Similarly, the organization of LBA settlements is also disputed, as some authors view the standardization of smaller longhouses as evidence of successful elite centralization,[45] while others view this as more egalitarian in nature.[46] The decrease in the size of LBA houses was likely due to a lack of resources resulting from the overexploitation of forested areas in Periods II and III in the EBA, represented by the change in construction practices from plank-built houses to wattle and daub.[47] Some scholars perceive this change as the "decline" and "collapse" of political structures.[48] However, when viewed through an anarchic perspective, this change may be viewed as the promotion of egalitarian ideals in a resource-limited economy and landscape.

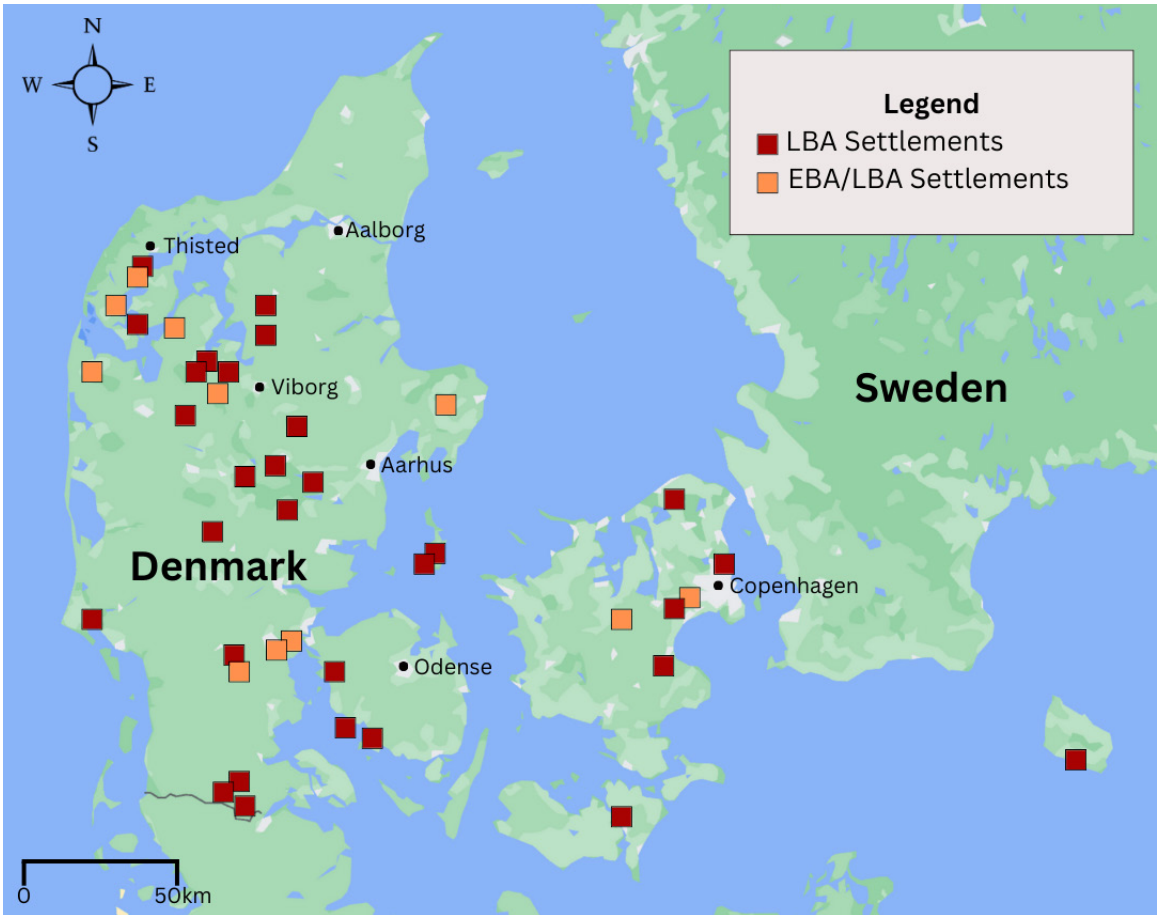

Figure 4. *Locations of Late Bronze Age settlements. Data was acquired from the Finds and Memories of the Past database from The Palaces and Culture Agency.*

CONCLUSION

As discussed throughout this paper, there is considerable disagreement and uncertainty in the literature regarding the sociopolitical organization of the Nordic Bronze Age. Most scholars agree that Bronze Age society in Scandinavia consisted of chiefdoms, which were often described as hierarchical and stratified in nature,[49] while also being fluid and unstable, and subject to changing power dynamics.[50] However, this ongoing debate largely revolves around differing perspectives of EBA and LBA burials and settlements. It is generally believed that Periods II and III of the EBA represented the height of hierarchical organization, which declined by Period IV of the LBA. Some scholars argue that the LBA saw the centralization of power among a few elites over the commoner mass,[51] while others disagree and believe it was characterized by more egalitarian-like ideals[52] and reduced social differentiation.[53]

The nature of the sociopolitical organization of the Nordic Bronze Age society can be difficult to ascertain due to the lack of archaeological evidence and the various conflicting scholarly opinions it creates. Anarchic theory acknowledges the presence of hierarchy in certain aspects of society but emphasizes the importance of individual autonomy, promotion of equitable relationships, and resistance to centralized control in favor of decentralization. These aspects persisted in society even as resources became scarce. While scarcity often leads to more centralized control, the LBA demonstrated the opposite by showing signs of decentralization and resistance to elite authority. This is seen in the archaeological record when houses became smaller and more standardized with a change in building materials and when burial practices moved from barrows to urns. While practices changed due to scarcity, they maintained a decentralized and equal nature.

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Teagan McIntosh '24 is an Anthropology major with a minor in Archaeology from College Station, Texas who went to high school at Saint Philips College in Alice Springs, Australia. Teagan is passionate about understanding how societies were organized in the past, which shaped her research interests and led her to be involved in programs such as the Anthropology Society and the Texas Archaeological Society. Teagan aims to attend graduate school to further explore these interests.

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In Between Divinity and Humanity: Heroism and Grief in the Iliad and the Mahābhārata

By Aarya Newasekar '26

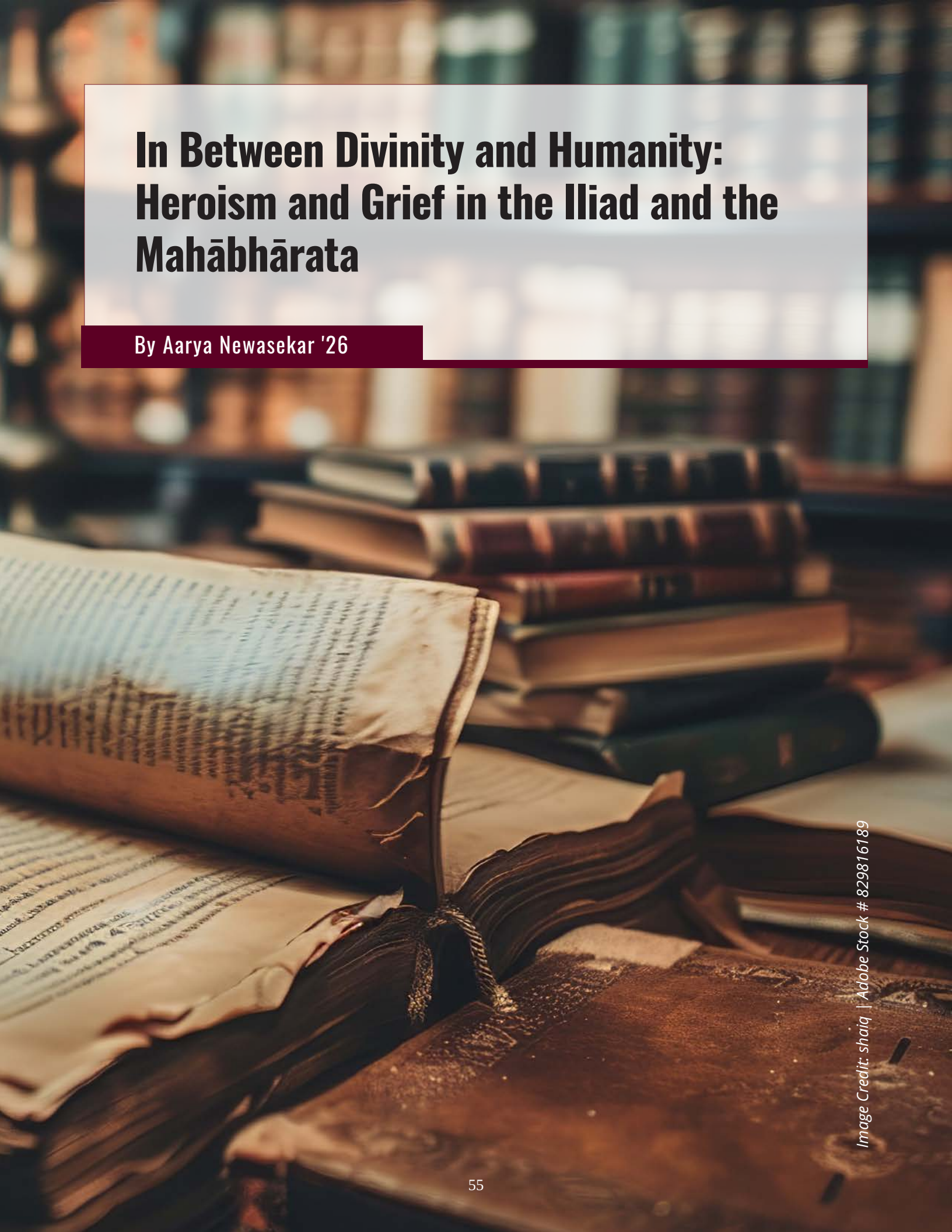

Image Credit: shaiq | Adobe Stock # 829816189

INTRODUCTION

Heroic myths have been a staple in storytelling traditions around the world for thousands of years. The ancient Greek epic the *Iliad*, and its ancient Indian equivalent, the *Mahābhārata*, are two such works. As monumental culture-defining texts, the *Iliad* and the *Mahābhārata* open a window to the cultures that composed them, providing a unique glimpse of the composer-cultures' worldviews and the values that they held in high regard.

Both of the epics are centered around war, which they treat as an opportunity to display awe-inspiring heroism and a conduit for debilitating grief. In reading the *Iliad* alongside the battle books of the *Mahābhārata* (books 6 - 11), a fascinating image of the ties between heroism and grief emerges. Champions of the foundational principles of their respective cultures, the heroes of both literary traditions are well-nigh deified through their behavior and military prowess. But while their heroism is manifested in divergent ways, the heroes are ultimately tethered back to their humanity through grief caused by the death of their loved ones.

THE EPICS AND THEIR SHARED HERITAGE

The *Iliad*, attributed to Homer, was probably composed sometime during the late eighth and early seventh centuries BCE. While the epic is far from a true historical account of events, it is not a wholly imaginary composition, and is thought to preserve memories of the Greek Bronze Age. It is a part of the larger literary corpus of the (now-lost) Epic Cycle, which recounts the entire narrative of the Trojan War from the Judgement of Paris to Odysseus' return home and later adventures. The *Iliad*, specifically, focuses on the events that take place during a few months in the tenth year of the Trojan War, and is thematically centered around the rage of the great Greek hero, Achilles.

The *Mahābhārata* on the other hand, at 100,000 couplets, is almost encyclopedic in its scope. Attributed to the prolific writer-sage Vyāsa, it was composed between 400 BCE and 400 CE. Like the *Iliad*, the *Mahābhārata* is neither a scholarly account of historical events, nor a wholly fictional story, and is often classified as a part of *itihāsa* (historical) literature in the Sanskrit tradition. It tells the story of a long-drawn strife between the heirs of the Kuru kingdom, located in modern day northern India, culminating in a devastating war between two sets of cousins: the five *Pāndava* brothers against the one hundred *Kaurava* brothers. The epic is tightly woven around what it considers to be the four pillars of human life: *dharma* (duty), *artha* (means of livelihood), *kāma* (desire), and *moksha* (liberation from the cycle of reincarnation).[1]

As products of rich, long-standing oral traditions, both the *Iliad* and the *Mahābhārata* make abundant use of a regular poetic meter, stock similes and epithets, and recurring, almost formulaic, scenes. Elements such as these likely would have served as memory aids for bards and are characteristic of oral compositions.[2] Other notable parallels between both epics can be chalked up to their shared Indo-European heritage.

The term "Indo-European" refers to the language family encompassing most languages native to Europe and central and southern Asia, of which ancient Greek and Sanskrit represent some of the oldest branches. The term also refers to the ancient speakers of the ancestor of these languages (often referred to as proto-Indo-European), who most likely lived in close geographical proximity. Their tongues diverged as they eventually migrated away from one another, but they carried with them their shared traditions of storytelling and poetry.[3]

These shared poetic traditions can be glimpsed in certain structural and narrative aspects of both the *Iliad* and *Mahābhārata*. Descriptions of battle are structured in remarkably similar ways, as infantrymen clash with infantrymen and chariot-warriors with chariot-warriors.[4] Book 10 of both epics feature a night raid conducted against the winning armies by the losing side of the war, while Book 3 involves an identification of kindred warriors by female protagonists. Both of these scenes, which display a striking resemblance in the way they unfold, are thought to reflect older Indo-European tropes of the nocturnal attack[5] and the customs surrounding the Indo-European institution of marriage by abduction,[6] respectively.

While comparing features shared by the two poems adds to our overall understanding of Indo-European language and culture, studying the *Iliad* and *Mahābhārata* as products of two very different cultures is equally illuminating. The differences and similarities found in the way the two war-epics deal with common themes of battle, heroism, and grief reveal priceless information about the values that both societies held in high regard, in particular, the goal of human life, and how they dealt with the notion of human mortality. The burden of illuminating these big ideas for audiences falls on the shoulders of the heroes of the *Iliad* and the *Mahābhārata*.

THE EPIC HERO

The way that both the epic traditions construct the concept of the hero is fascinating. Neither text has a word for "hero" that has the same specificity that the English word wields. The *Iliad* uses the word "*hērōs*" to refer to any major warrior participating in the Trojan War,[7] whereas the *Mahābhārata* uses the words "*vīra*" and "*shūra*"—both adjectives simply meaning "courageous"—for all warriors.[8] While military prowess and fortitude are indeed priceless assets, there is something more to an epic hero that prevents every brave and skilled warrior from earning the same status. This is best illustrated by examining the central heroes of the epics: Achilles from the *Iliad* and Arjuna from the *Mahābhārata*.

The *Iliad* begins with the bard invoking the Muse to "sing the rage of Peleus' son Achilles,"[9] establishing the theme around which the epic revolves. The enraged withdrawal of Achilles, the son of a royal mortal father, Peleus, and a divine mother, Thetis, from the Greek war effort after a quarrel with Agamemnon, the commander of the Greek forces, sets up the events that transpire throughout the epic. As he is one of the most skilled warriors on the Greek side, Achilles' refusal to fight considerably weakens the Greek forces, who are immediately overwhelmed by the Trojans. The tide of the battle is decisively turned in their favor only when Achilles rejoins them wearing armor and wielding a shield forged especially for him by the god Hephaestus.

Throughout the *Iliad*, Achilles is almost godlike in his "murderous"[10] wrath. He isolates himself in his camp away from the rest of the Greek commanders, apathetic to their hardships caused by his absence, even as they try in vain to placate him with speeches, praise, and gifts—the same methods used to propitiate raging gods throughout the epic. The only thing that succeeds in bringing Achilles down from this godly plane is the heart-crushing sorrow he feels at the death of his companion Patroclus. Thus, Achilles, semi-divine by birth, wielder of godly arms, and divine in his rage, is wholly humanized in his grief.

"NEITHER TEXT HAS A WORD FOR "HERO" THAT HAS THE SAME SPECIFICITY THAT THE ENGLISH WORD WIELDS"

The *Mahābhārata* does not focus on one central epic hero like the *Iliad*. It does, however, spend a long time recounting the accomplishments, exploits, and travels of Arjuna, the third of the five *Pāndava* brothers, who are the protagonists of the epic. The son of a royal, mortal mother, Kunti, and a divine father, Indra (the king of the gods), he plays a pivotal role in ensuring his brothers' victory over their 100 cousins. Arjuna, renowned as an archer par excellence, capable of holding off entire armies on his own, is practically deified by his skill. He is gifted a divine bow, the *Gāndīva*, and the *Pashupatāstra*, a divine weapon capable of immense destruction, to aid in the war effort against his cousins.

What is interesting about Arjuna's characterization is that, unlike Achilles, he is often treated as a fully divine being. Of all of his brothers, only he is extremely close to their maternal cousin, Krishna, who, according to varying traditions, is either an incarnation of the god Vishnu or is the Supreme Being himself. So tight-knit is their bond that the two are often equated with one another as "the two Krishnas."[11] The epic also sometimes identifies Arjuna and Krishna as reincarnations of the

legendary divine sage duo Nara and Nārāyana.[12] This characterization of Arjuna as fully divine, however, is never an important plot point, nor do most characters, including Arjuna himself, seem to have any knowledge of it. This characterization, then, can likely be put aside as either a newer addition or a holdover from an ancient tradition that lost influence over time.

Therefore, like Achilles, Arjuna is a hero of semi-divine parentage, who spends much of his epic in a god-like plane achieved via his astounding proficiency in warfare. Arjuna aids the gods, receives divine gifts, secures an ally for his brothers through a seemingly impossible archery contest, and almost single-handedly wins the war of the *Mahābhārata* through his military prowess. Arjuna is a man of action, and it is only in the aftermath of his son Abhimanyu's death in battle that he understands what it means to be helpless. Just like his Greek counterpart, Achilles, he is ultimately humanized through his grief.

THE HEROIC GOAL

Having examined the individual characteristics of the epic heroes that seem to deify them—Achilles' anger and Arjuna's dexterity with the bow—it is also necessary to consider how both heroes are further distanced from their humanity in their single-minded, successful pursuit of a Heroic Goal. Unlike the heroes' godlike wrath and skill, this dogged quest for the Heroic Goal is tied to larger societal ideas about the purpose of human life.

The highest honor that a Greek hero can achieve is obtaining *kleos*—everlasting fame and glory. Much of the action throughout the *Iliad* hinges on this one crucial element of ancient Greek society. During his argument with the commander Agamemnon in Book One, Achilles complains that his "honors never equal [Agamemnon's]"[13] and threatens to go back home. Agamemnon retorts that it makes no difference to him if Achilles leaves, as he is "nothing" to him.[14] Agamemnon's declaration and his subsequent confiscation of Achilles' war-prize, Briseis, makes Achilles realize that he will never find the *kleos* that he is searching for within the current status quo. As a result, he withdraws from what is, in his eyes, an entirely futile endeavor.

This theme of everlasting fame and glory also appears in Thetis' prophecy which Achilles reveals to the embassy of the Greek leaders sent to persuade him into rejoining the battle in Book Nine, saying,

> two fates bear me on to the day of death.
>
> If . . . I lay siege to Troy, my journey home is gone, but my glory never dies
>
> If I voyage back to the fatherland I love,
>
> my pride, my glory dies . . .
>
> true, but the life that's left me will be long.[15]

Although in light of Agamemnon's insults, Achilles initially considers the latter option, he eventually ends up choosing undying glory in exchange for a short life.

In a culture as competitive as that of the ancient Greeks, it is no wonder that a quest for fame and glory is the greatest preoccupation of their cultural heroes. The societal emphasis on the pursuit of *kleos* can also be viewed in the context of the finality of the Greek afterlife. In early ancient Greek religion, a man lived, died, and then journeyed to the Underworld, a grim, dark place,

"IN A CULTURE AS COMPETITIVE AS THAT OF THE ANCIENT GREEKS, IT IS NO WONDER THAT A QUEST FOR FAME AND GLORY IS THE GREATEST PREOCCUPATION OF THEIR CULTURAL HEROES"

where he would continue to exist as a mere shade for the rest of eternity.[16] Within such a worldview, the only shot mortals have at some semblance of immortality is via the undying memory of their great feats passed down for generations to come, or *kleos*. Obtaining such everlasting glory, however, is a task which is practically unattainable by most common individuals. Thus, Achilles' successful acquisition of the *kleos* owed to him serves to bolster his quasi-divine heroic identity.

On the other hand, the Heroic Goal of the Sanskrit epic hero centers around the preservation of *dharma*, which can be taken to mean both duty and order. The Heroic Goal, therefore, is both to stay true to one's *dharma* (duty) and in the process preserve the *dharma* (order) of the world. This is a constant point of discussion throughout the Mahābhārata, with the most significant being the episode of the *Bhagavad Gītā* found in Book Six of the epic. Seeing his family members arrayed on both sides of the battlefield, Arjuna wonders whether killing his cousins, uncles, grandfathers, and teachers would really result in the preservation of *dharma*. He observes that the war will wreak havoc on the kingdom and his family, which would lead to the destruction of ancient familial laws, and by extension, the laws of the land.[17] Surely, Arjuna argues, that must be the opposite of his Heroic Goal of upholding the *dharma* of the world.

Krishna, who plays the role of Arjuna's charioteer, points out that not fighting would also hinder the achievement of his goal, as that would be violating his *dharma* as a warrior. The two go on to have a lengthy discussion about the nature of *dharma*, at the end of which Arjuna comes to the realization that it is only by sticking to one's own *dharma* that one can preserve the *dharma* of the world. He goes on to take part in the war whole-heartedly, winning victory for his side.

The ideals of *dharma*, *karma* (good actions result in good effects, bad ones in bad), and *samsāra* (the cycle of reincarnation) weighed heavily upon the minds of the ancient Indians. In light of these philosophical concepts, it makes sense that the heroes of such a culture would devote their lives to fulfilling their duties and establishing and preserving the order of the world. Not only was doing good in the world a certain way of ensuring benefits both in this life and the next, selflessly carrying out such tasks allowed one to be liberated from the bondage of *samsāra*. Like Achilles' achievement of *kleos*, Arjuna's unflinching dedication to following and preserving *dharma*, even if it meant slaying members of his family, only serves to deify him, further distancing him from his humanity.

THE HERO'S GRIEF

If certain individual characteristics and an unwavering commitment to different, culturally significant Heroic Goals makes the epic hero appear quasi-divine, they are both pulled back down to their humanity via grief. The sequence of Heroic Grief is set up in remarkably similar ways in both epics. In the *Iliad*, Achilles' companion Patroclus, wearing Achilles' armor, stands in for him, leading the Greek armies up to the walls of Troy, where he is killed in a grossly unfair fight with several Trojan warriors and the god Apollo. In the *Mahābhārata*, with Arjuna being lured away to a remote part of the battlefield, his young son Abhimanyu stands in for his father and attempts to break through a complex battle array within which he is simultaneously attacked by several warriors and is killed.

Here, it is interesting to note the choice of character killed. Both Achilles and Arjuna, being warriors, have seen many be killed, but only the deaths of Patroclus and Abhimanyu shatter their spirits. These characters are extremely close to the heroes, who see them almost as extensions of themselves. Thus, their deaths force the heroes to come to terms, likely for the first time, with their own mortality.

Despite being characterized in different ways, both heroes react in remarkably similar ways to the news of the death of their loved ones. After Patroclus has been slain, Homer tells his audience that

> A black cloud of grief came shrouding over Achilles.
>
> Both hands clawing the ground for soot and filth,
>
> He poured it over his head, fouled his handsome face

> And black ashes settled onto his fresh clean war-shirt.
>
> Overpowered in all his power, sprawled in the dust,
>
> Achilles lay there, fallen[18]

Meanwhile, Vyāsa recounts Arjuna's several pages-long heart-breaking lament for his son's death, as he "[wails] out like a poor man whose mean things had been sucked into the sea"[19] that

> "There was only one among you who could break [the array]. My little [Abhimanyu] . . . What peace can there ever be in my heart if I cannot see my boy's noble face . . . if I cannot hear his voice . . .? My heart must be made of diamond that it does not break apart into a thousand pieces."[20]

Both of these descriptions are extremely pitiable, as for the first time in their heroic careers, the epic heroes are seen as entirely helpless, grieving victims. In this way, they become one with the scores of mortals around them, weeping over the bodies of family and friends, whom they have lost to the war. Although these scenes of mourning are but brief breaks in the heroes' god-like demeanors, which are put back on as they seek revenge, the fact that grief is the only emotion that successfully humanizes them is endlessly fascinating. No matter how courageous, powerful, and skilled the heroes may be, they are still incapable of protecting those whom they love, and ultimately themselves as well, from death. The very moment they realize this, all their godly pretenses fall away and are replaced by the painfully human feeling of loss.

CONCLUSION

Both ancient Greek and Indian cultures were preoccupied with trying to make sense of the human condition. The *Iliad* and the *Mahābhārata* are some of the most significant ways in which these cultures tried to answer such questions. A comparative study of the way in which the epics handle the themes of heroism and grief reveals that, although the former is often depicted in a myriad of ways, and is at least partially dependent on culturally important values, scenes of heroic grief are strikingly similar, as across cultural, spatial, and temporal boundaries, people always die to the same effect. Thus, the *Iliad* and the *Mahābhārata*, like their heroes, are brought together in their heart-felt expressions of humanity.

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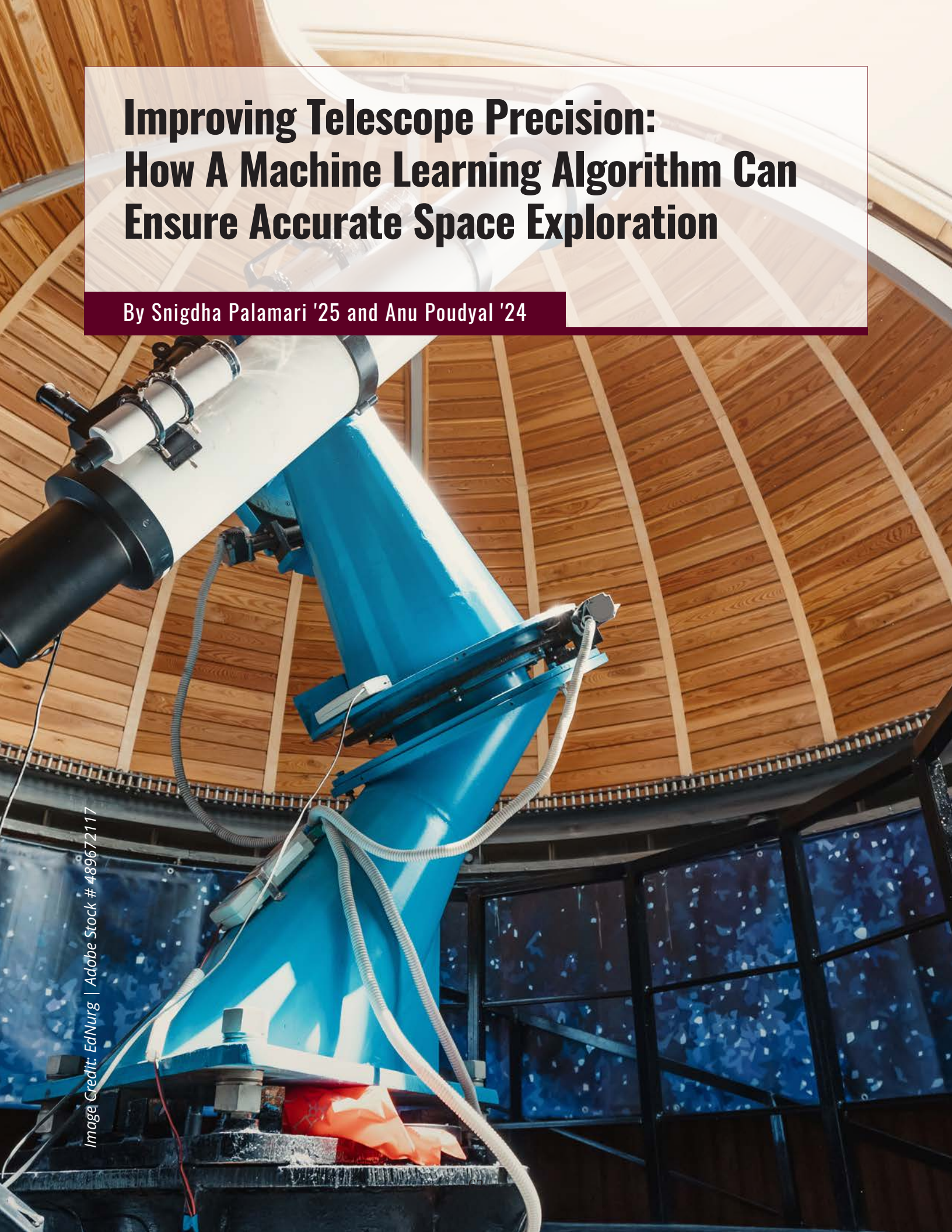
Improving Telescope Precision: How A Machine Learning Algorithm Can Ensure Accurate Space Exploration

By Snigdha Palamari '25 and Anu Poudyal '24



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INTRODUCTION

Since their invention, space telescopes such as the Hubble Space Telescope (HST), and its successor, the James Webb Space Telescope (JWST), have been essential to space exploration. These telescopes can capture imagery of celestial objects light years away. The telescopes achieve this using their Fine Guidance Sensors to lock onto a specific star also known as a guide star. However, despite being humanity's most powerful telescopes, both the HST and JWST currently have a 0.6 percent guide star acquisition failure rate, meaning they fail to lock on to the guide star 0.6 percent of the time.[1] Guide stars, which are important in determining the attitude and pointing of the telescope in an astronomical mission, can result in an acquisition failure when the system is unable to point to it properly. Though a seemingly low number, each failure has significant consequences: For every guide star acquisition failure, the associated research is delayed or ignored completely, which costs time and may deplete resources. Furthermore, single-star guiding is dependent on the telescope's rotation, and over time, the amount the telescope drifts away from the intended target can increase until a second star is located. This can cause observational delays resulting in needed corrections for both the data and images.[2] Currently, the HST and JWST utilize a manual and automated approach respectively. In determining potential guide stars, the HST using a Guide Star Catalog (GSC) and the JWST a guide star selection system.[3] However, this approach does not avoid the 0.6 percent failure rate.

Issues caused by attitude determination, or the orientation of the telescope, such as telescope positional accuracy and rotation, can be mitigated by generating a new GSC using the Spherical Binary K-means clustering algorithms.[4] Considering the machine learning algorithm's ability to remain a non-supervised algorithm (meaning it does not require labeled data for training) while efficiently creating results, the K-means algorithm fixes GSC issues while maintaining a straightforward process that is easy to both visualize and use. However, the K-means algorithm, and its other variants are susceptible to data outliers. Namely, stars too distant from other stars that prevent accurate clusters from being formed. Measurement errors or noise could impact the decision for the optimal guide star candidates where maximum accuracy is needed.

“MEASUREMENT ERRORS OR NOISE COULD IMPACT THE DECISION FOR THE OPTIMAL GUIDE STAR CANDIDATES WHERE MAXIMUM ACCURACY IS NEEDED”

Our project aims to use the K-medoids algorithm, which is a variant of the K-means algorithm, on the Guide Star Catalog II (GSC II) to determine the optimal guide star candidates for the area of the mission. In general terms, the K-medoid algorithm is a clustering algorithm that finds the centers of clusters within a given dataset. This algorithm is an unsupervised machine learning algorithm that can detect patterns (the so-called clusters) in the data set such that the distance between each of the data points is minimized to the center of a cluster. These cluster centers are known as medoids. Our objective is to accomplish this by preparing the data in the GSC II to eliminate stars that are most likely to cause acquisition failure and instead find the optimal stars through the K-medoids algorithm.

DATA COLLECTION AND PREPARATION

The GSC II has several key factors that are essential to its compatibility with this algorithm. Firstly, the GSC II is recognized for its comprehensive selection of guide stars from several astronomical surveys which are collections of celestial objects and stars. These surveys include the Digitized Sky Survey and Tycho-2.[5] GSC II contains precise information for millions of stars from these surveys and thus has optimal coverage for astronomical observations. Finally, the GSC II contains the necessary parameters that can be used to determine the

best stars to use for the algorithm as it pertains to clustering. By eliminating stars that are more likely to cause guide star acquisition failure, these parameters allow a screening process prior to clustering.

The initial step of preparation involved selecting a sample set of stars that was then used to test the algorithm. These stars were placed on a coordinate-grid system where the Right Ascension (RA) can be thought of as the x-axis and the Declination (Dec) as the y-axis. As with any measurements, there are errors associated with the RA and Dec, and an inaccurate reading can impact the Attitude Determination System (ADS), causing guide star failures. The guide stars with more significant errors could cause issues with the telescope's pointing abilities, which lead to the acquisition failures. By removing the stars with greater RA and Dec errors, we created a smaller number of stars to test and train with.

The next parameter screened was the proper motion of the stars, which is defined as the angular velocity that the star travels with across the celestial sphere.[6] Guide star acquisition can be significantly impacted by this phenomenon, especially in long-duration observations. This can cause a change in pointing during the observation and keep the telescope from maintaining its position. As such, stars with higher proper motion are less likely to be successful guide stars due to their propensity to cause misalignment in the field of view. As a result we prepared the data by removing stars with higher proper motion. Through this step, we were able to mitigate the risk of pointing errors and find stars that are more reliable.

Due to the differences in magnitude requirements across telescopes, the next parameter we focused on was the magnitude (the measure of brightness of the star) of these guide stars. For the JWST, the optimal range for guide stars is between 12.5 and 17.8 magnitudes.[7] We used his range to simulate real-world conditions. However, since this range may vary across telescopes, we included the ability to adjust the magnitude as an accommodation to other telescope requirements. The addition of this parameter allows the incorporation of different telescopes during the guide star selection process while assuring that magnitude specifications are met.

Another parameter considered was that stars can seem to shift in position when viewed from two widely spread points.[8] This is called parallax and must be carefully considered for the selection process since stars that have more parallax can cause several positional inaccuracies due to a larger displacement and impact the pointing of the telescope. Through analyzing the parallax of the guide stars, we were able to identify the stars that have less parallax effects and ensure stability of the pointing precision.

Arguably one of the most important parameters is the Point Spread Function (PSF). This function describes how the telescope and atmosphere can cause blurring and impact astronomical observations. The blurring it describes can cause positional errors in the telescope since the pointing accuracy will be impacted by the point spread of the observed star. Guide stars with a lower point spread are ideal due to minimal distortion and a clearly available center. They are also less likely to cause pointing errors and make the telescope less susceptible to rolling.[9] This is especially important in research that must have higher resolution or precision.

The GSC II contains one final parameter that is necessary to include while selecting the ideal guide stars for the mission. Although this occurs rarely, the multiple flag is an important criterion to be mindful of as it refers to guide stars that are a part of a binary or several star structures, which is a threat to positional accuracy since they can have higher point spreads and thus cause acquisition failures.

OPTIMAL GUIDE STAR IDENTIFICATION

The K-medoid algorithm itself is not too complex: k random points are selected from the dataset, where the value k is the initial number of clusters that needs to be chosen prior to running the algorithm on the data set. Once this value is determined, the algorithm randomly selects k data points in the dataset to be the medoids. The algorithm then runs through all the data points and assigns each of them to a medoid, which become the initial clusters. The factor that determines which data point belongs to which cluster at this point is the distance between each data point and medoid. The

cluster is made up of the points that are closest to each medoid. Once the initial clusters are determined, the sum, known as the cost, of the total distances from each data point to the medoid for each cluster is calculated.[10]

After the initial cost is determined, the algorithm will swap the medoid for every non-medoid point within the cluster and recalculate the total cost of each potential medoid. Then it will look at all the previously calculated costs and do one of two things: If the current cost is greater than the previous cost, then the swap is undone and the algorithm stops. If the current cost is less than the previous cost, then the previous step is repeated. **Figure 1** is a condensed version of the K-medoids algorithm constructed in pseudocode.

To adapt the K-medoid to find optimal guide stars to minimize guide star acquisition failures with the JWST, a few modifications need to be made. Specifically, with the initial selection of the clusters. Instead of letting the algorithm decide the medoids completely randomly, it will choose from a prescreened selection of guide stars for the medoids, mainly those with lower error rates. Therefore, the medoids will be chosen from guide stars that are most likely to be successful according to the JWST criteria. This is also the case during the reselection portion of the algorithm.

Algorithm 1 K-medoids Algorithm

Require: K = number of clusters
D = data set
n = number of points in data set
m = medoid
s = cost
Initialize variables
Conduct pre-processing
Randomly select m
Check if m is a viable guide star
for p in D **do**
find the nearest m and assign p to the correct cluster
end for Calculate s
Check s value
Repeat

Figure 1*: Pseudocode for the algorithm.*

RESULTS

Validation and Testing

To determine if the K-medoids algorithm was able to choose the ideal guide star, we used a Monte Carlo approach. Generally, the Monte Carlo Simulation uses mathematical methods to simulate possible outcomes for any event. The predictions that the simulation makes are based on a given range of estimated values. The main purpose of the Monte Carlo Simulation is to analyze the data and predict an outcome, depending on the course of action present. The Monte Carlo Simulation uses the normal distribution curve to determine the uncertainty of a given variable. The simulation then recalculates the results many times with different random values that are within the set range. The simulation can generate many possible outcomes, and as it continues with each sample, the outcomes become increasingly more accurate. In the end, the outcomes follow the normal distribution curve with the most common outcomes occurring in the middle of the curve and the least common on the outer edges.[11]

To implement the Monte Carlo Simulation, the initial step is to construct the algorithm. The next step is to select the variables to run through the simulation, making sure that the variables selected are well-distributed across the data set. After that is complete, the simulation is run and then rerun several times to perform the repetitive iterations. The last step is to conduct the data analysis on the results of the simulation.[12]

For the purposes of testing, a galactic coordinate system was included in order to avoid a field of view with an incredibly dense number of stars. The Monte Carlo Simulation was primed with this coordinate system to ensure that the algorithm did not fail due to its inability to meaningfully separate dense populations of stars. Since this algorithm relies heavily on the computation of the distances between the stars, denser populations are incredibly difficult to mitigate. Therefore, the galactic coordinate system of the Milky Way galaxy is essential to the testing of the algorithm.

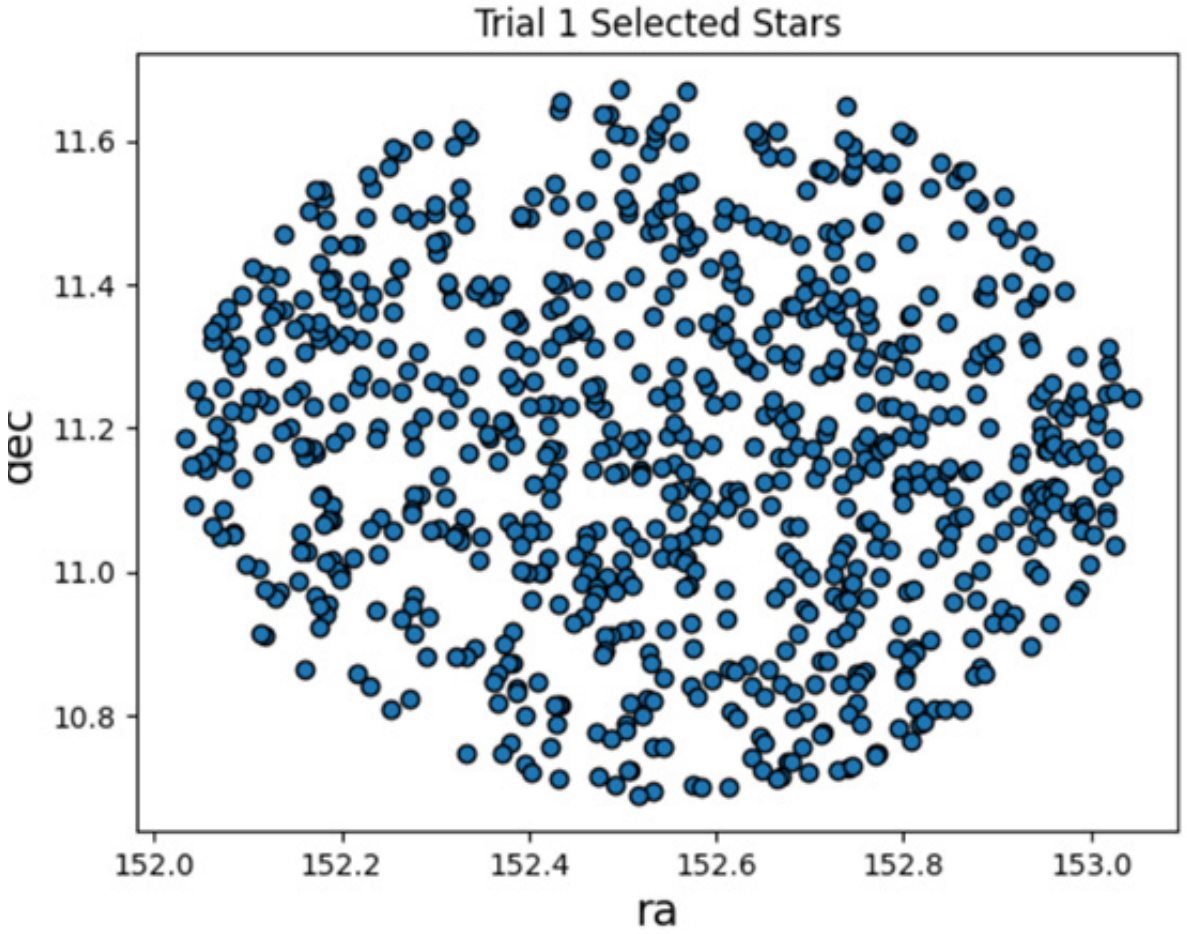

Figure 2*: Plots (created using Python) of the RA and Dec for a field of view of 30 arcminutes used to initially test the algorithm.*

Figure 2 displays all the guide stars given from the guide star catalog with respect to their right ascension and declination, and **Figure 3** displays the same guide stars after three iterations of the K-medoids algorithm were run on the data. As one of the parameters of the algorithm, *k* was set to the number of processed stars divided by 100 and this returned the clusters and proposed guide stars (represented in cyan in the figure). According to the algorithm, those are the guide stars that are in the center of each cluster and will have the least likely chance of causing a guide star failure.

To test this algorithm, we applied the Monte Carlo Simulation by downloading 147,392 guide stars from the GSC II and cross-checked the results of the algorithm against the criteria for officially validated results. The optimal guide stars had to be within the range specified in the criteria but also account for magnitude listed in the parameters to avoid over saturation or faint stars. Additionally, the algorithm also had to find these stars with the criteria that the surrounding environment of each selected guide star had no "spoiler stars" within six arcseconds.

After running the simulation, we found that the algorithm had an accuracy rate of 97.16 percent, which implies that 97.16 percent of the guide stars selected as optimal by the algorithm adheres to the JWST criteria.

CONCLUSION

This study was dedicated to finding guide star candidates least likely to cause guide star acquisition failures by using the K-medoids clustering algorithm on the GSC II. First, the stars found in the selected FOV were screened according to parameters that cause acquisition failures. Next, the K-medoids clustering algorithm was applied to the data set, which selected the candidates us-

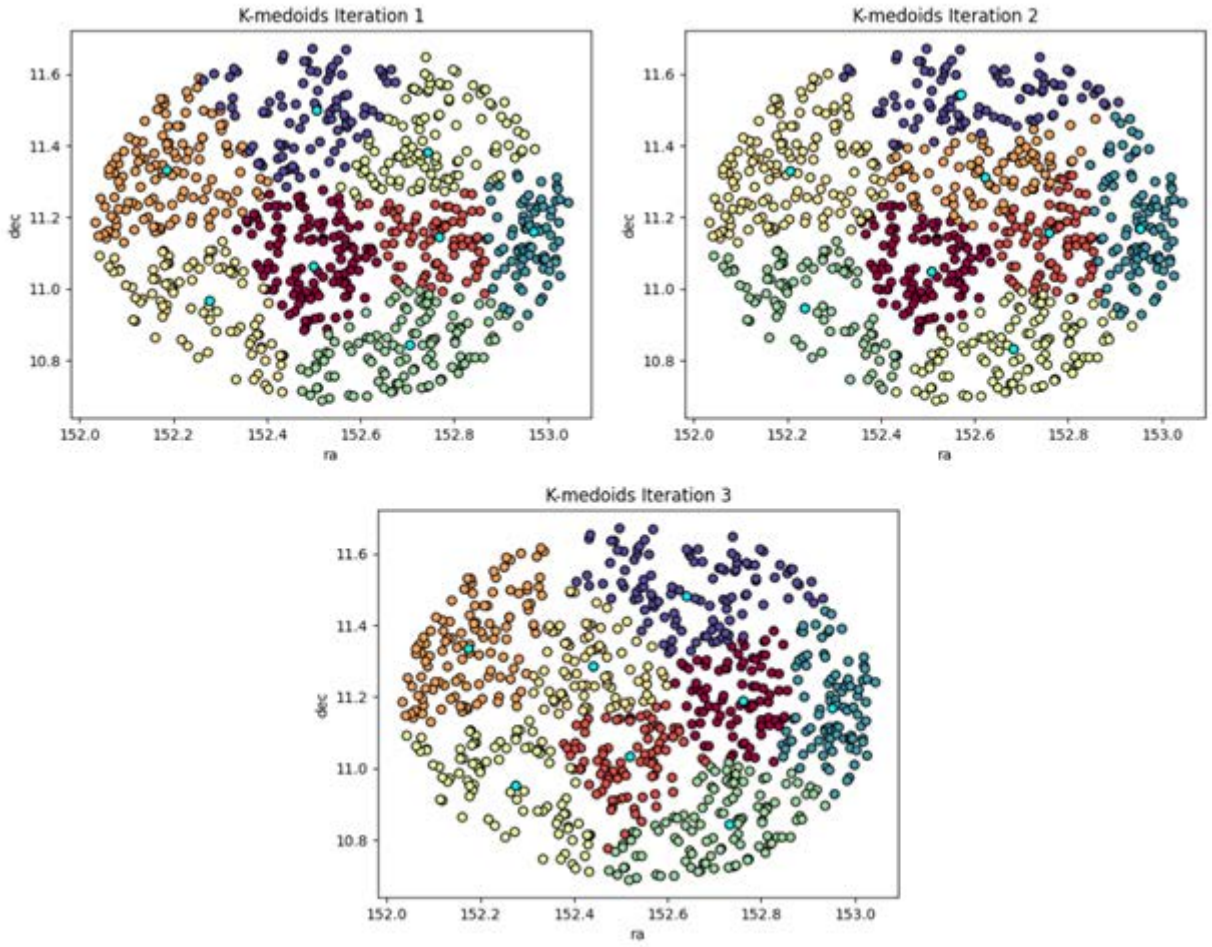

Figure 3*: Plots (created using Python) after the three iterations of the K-medoids algorithm were run on the selected stars. The cyan dots are the medoids and the other colors represent the clusters.*

ing the JWST guide star criteria, including magnitude and the impact of spoiler stars. The results determined by the algorithm show that directly using stars as starting points reduced the impact of outliers and noise on the accuracy of the guide star. Moreover, cross-checking the selected stars with the criteria returned a significant probability for at least three potential guide stars within several different fields. This shows that the algorithm successfully satisfies the JWST criteria and provides a foundation for future research in machine learning and astronomy. As machine learning advances, computational efficiency and accuracy will also improve. Conclusively, the K-medoids algorithm was proven to be successful in mitigating the impact of guide star acquisition failures in astronomical research. This capability underscores its significance as a valuable tool in navigation for celestial exploration.

A limitation of this research is that the GSC II is outdated compared to newer available versions of star catalogs. For instance, the Gaia Data Release 2 was published in 2018 (compared to the GSC II release in 2016).[13] Considering that the K-medoids has been trained using the GSC II, it is possible to adapt it with newer guide star catalogs that are available in the future. Other limitations include the primary use of the JWST to set up the parameters for this study. Although incredibly advanced, the JWST will eventually have a successor due to technological advances, and the parameters themselves may need to be updated as technology is able to better automate processes, have faster computational processing, and when more techniques for artificial intelligence/machine learning techniques become more available. Furthermore, as automation advances, the selection process itself may become easier, using real-time techniques rather than the parameter preparation done for this study.

The complexity of the K-medoids algorithm increases for larger data sets. This can cause issues with

processing times as well as reduced efficiency when viewing extremely large data sets. As such, one of the best areas for improvement for this algorithm is the efficiency. As machine learning advances, this issue can be resolved.

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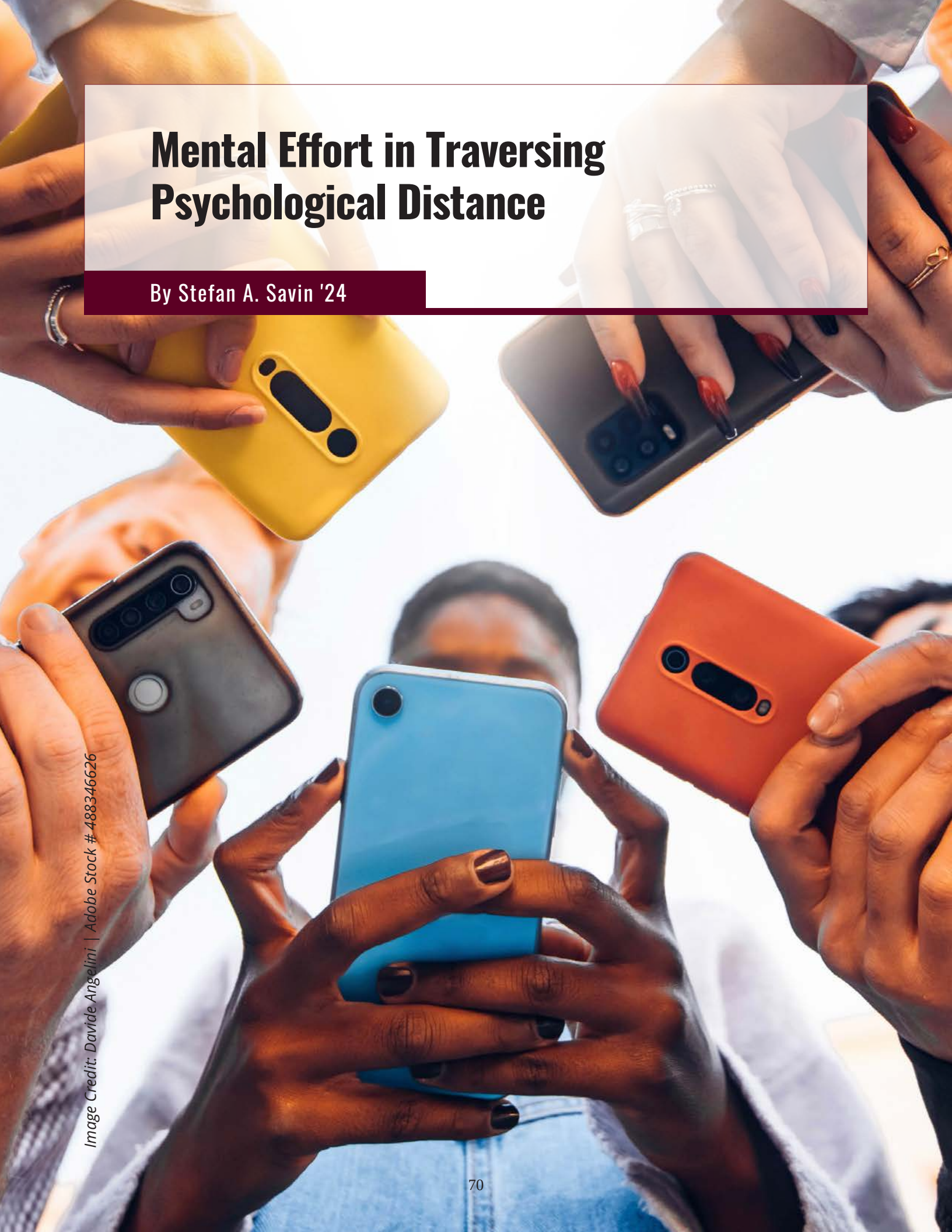
Mental Effort in Traversing Psychological Distance

By Stefan A. Savin '24



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INTRODUCTION

College students love to use their smartphones, but eventually even the most obsessive users put their phones down. The act of putting one's smartphone away can be mentally represented (construed) in several ways. At a basic or concrete level, putting a smartphone away could be construed as turning the volume down and zipping it up in a backpack. At a higher, more abstract level, the same action could be construed as taking a mental health break. Both construals accurately characterize the action, but they do so at different levels of abstraction. The question arises as to whether one mode of construal requires more mental effort than the other. The present experiment tested this idea by considering the mental effort required to represent events at varying levels of abstraction.

Construal Level Theory

Construal level theory (CLT) seeks to explain how individuals complete mental tasks such as planning for the future, empathizing with others, or speculating about hypotheticalities.[1] The theory proposes that individuals accomplish those tasks "by forming abstract mental construals of distal objects."[2] According to CLT, construal levels pertain to the details of an event and can vary from low-level (concrete) construal to high-level (abstract) construal. Higher levels of abstraction correspond to a reduction in fine detail. In other words, if a person is less specific about an event, then they will tend to construe it in more abstract terms. By contrast, nearer or proximal events tend to be construed in more concrete, specific, and precise terms.

As an example, "having a snack" is an abstract construal of the more concrete action of "eating a bag of cheese crackers," which in turn is more abstract than "chewing crackers with my mouth." The action is the same across all three instances, but some ways of thinking about it are more abstract than others. Abstract representations are not simply less detailed versions of concrete representations; rather, they are a broader, more encompassing version. They represent the proverbial forest to the trees.

> "ALL EXPERIENCES HAVE A STARTING POINT"

Psychological Distance

Central to CLT is the idea of psychological distance. All experiences have a starting point. The direct, immediate experience of the individual is the point of "zero distance" (i.e., the here and now). Any other experience or event not directly observed in the present moment entails at least some psychological distance and must be mentally construed.

Past research has observed that, as psychological distance increases, construal level also tends to increase. Hence, high-level construals are more likely the farther away an individual is from an event. For example, a person will tend to use more concrete details when describing dinner tonight (spaghetti and meatballs with bread and a salad) versus dinner one week from tonight (Italian).

Psychological distance is a multifaceted concept encompassing four distinct dimensions: temporal distance, spatial distance, social distance, and hypothetical distance. Temporal distance refers to how near or far an event is in either direction of time (i.e., past or future). Spatial distance refers to how physically near or far an individual is from an object or event. Social distance refers to the relations between oneself and other individuals. Last, hypothetical distance pertains to an event's likelihood.

Construal Levels and Mental Effort

The current research tested the mental effort required to think in more abstract terms versus more

concrete terms, specifically in relation to events that vary in psychological distance. Mental effort refers to the subjective experience of doing mental work. Mental effort is typically experienced as unpleasant or aversive, and all else being equal, people prefer to avoid expending mental effort.[3] Hence, if some forms of construal are experienced as more effortful than others, then that may help to explain why people are less likely to generate those types of construals.

Past research has observed at least two tendencies that may be relevant for the current research: The first is that people tend to think in more abstract terms most of the time and they shift toward more concrete levels of construal mainly when something goes wrong (e.g., they make an error).[4,5] Hence, more abstract construals tend to be the automatic or default mode. It was therefore hypothesized that abstract construals would be experienced as less difficult or effortful compared to more concrete construals.

Second, psychologically near events should be easier or less effortful to construe than psychologically distant events. Near events are more tangible and real and hence should require less mental effort to construe. In the most extreme case, events happening at the current moment, and in one's immediate environment, hardly need to be construed at all; they can simply be sensed and experienced. By contrast, psychologically far events are less tangible and more uncertain and thus should require more mental work to construe. We therefore hypothesized that near events would be less effortful to construe compared to far events.

Furthermore, evidence suggests that individuals have a habitual tendency to think in more abstract terms about more distant events but think in more concrete terms about nearer events.[2] It is thus reasonable to expect that psychological distance (near or far) and construal level (concrete or abstract) combine to influence subjective experiences of effort. In the study reported below, participants were asked to consider both near and far events in both abstract and concrete terms. Based on the tendencies described above, it was hypothesized that construals that conflict with habitual tendencies would be experienced as more difficult or effortful. More precisely, we expected concrete construals of near events and abstract construals of distant events to be easier than their opposites (i.e., concrete construals of far events and abstract construals of near events), and that this would hold true across all four dimensions of psychological distance.

METHODS

Participants and Design

One hundred fifty-seven participants ranging from 18 to 22 years of age (M = 18.7, SD = 0.91) participated in exchange for credit toward a course requirement. The sample included 53 men and 104 women, with 93 being White participants, 28 Hispanic or Latino (White), 21 Asian, 7 reporting more than one race, 6 Black or African American, and 2 Hispanic or Latino (Black or African American). The study used a 2 (Psychological Distance: near or far) × 2 (Construal Level: concrete or abstract) × 4 (Dimension: hypothetical, temporal, social, or spatial) within-subjects experimental design.

Procedures

Participants reported individually to a small laboratory room, where an experimenter welcomed them and described the study. After consenting to participate, participants provided basic demographic information (e.g., age, race, ethnicity, and country of birth).

Participants were then asked to visualize and briefly describe a series of hypothetical scenarios. To begin, the experimenter read an example scenario: "You check out a book at a library in another country." Below the example scenario was one response showing how to respond to this scenario in a more concrete way and a second response showing how to respond in a more abstract way. The example was intended to give participants a framework for how to respond to the scenarios as instructed.

Participants responded to 16 scenarios presented in one of six randomly determined orders. The scenarios featured the four different domains of psychological distance: hypothetical, temporal, social, and physical. Participants responded to two scenarios representing each domain. Half of the scenarios concerned a psychologically near event and half concerned a psychologically far event; this was the distance manipulation. For half of

the scenarios, participants were instructed to think of the scenario in concrete terms and to think of the other half of the scenarios in abstract terms; this was the construal level manipulation.

For each scenario, participants were instructed to mentally represent the event and provide a brief written account of how they visualized that event to be. After each scenario, participants rated how effortful it was to visualize the scenario as instructed. Specifically, participants were asked the following five questions:

1. "How much effort did you expend thinking about this scenario?"
2. "How mentally fatiguing was it to think of yourself in the scenario as instructed?"
3. "How mentally demanding was the task?"
4. "How hard did you have to work to accomplish this task?"
5. "How did thinking about this scenario make you feel?"

Participants responded to the first four items using a scale from 1 (*none at all*) to 7 (*a great deal*), and to the final item using a scale from 1 (*very unpleasant*) to 7 (*very pleasant*). Responses to these five items for each scenario were averaged together, and the average scores served as the primary dependent measure for the study.

After completing the 16 scenarios, participants were instructed to knock on the door to bring the experimenter back into the laboratory to explain the next steps. Following completion, the experimenter debriefed participants about the purpose of the study and thanked them for their participation. The study procedures lasted approximately 60 minutes from start to finish.

RESULTS

We conducted a 2 × 2 × 4 repeated measures analysis of variance (ANOVA) on participants' average response to the five self-reported items that followed each scenario. We found three main effects and one interaction, as described below. Data from one participant was excluded from analyses because that participant did not complete all components of the study.

First, we found a main effect of construal level, $F(1, 156) = 8.65$, $p = .004$. Concrete events ($M = 3.42$) were more effortful to visualize than abstract events ($M = 3.30$). Next, we found a main effect of distance, $F(1, 156) = 13.96$, $p < .001$, such that far events ($M = 3.41$) were more effortful to construe than near events ($M = 3.30$).

We also found a main effect of dimension, $F(3, 468) = 3.79$, $p = .011$, and followed up with Tukey's HSD post-hoc tests to identify where the differences lie. The hypothetical dimension ($M = 3.30$) was less effortful to visualize than both the spatial dimension ($M = 3.39$), $p = .010$, and the social dimension ($M = 3.37$), $p = .042$. None of the other pairwise comparisons were statistically significant.

We also found an interaction between dimension and distance, $F(3, 468) = 7.98$, $p < .001$. Tukey's HSD post-hoc tests revealed that this interaction was driven by the hypothetical dimension, which was more effortful to visualize in further distances than nearer ones, $p < .001$. As depicted in **Figure 1**, near events were less effortful to visualize than far events in all dimensions except the social dimension.

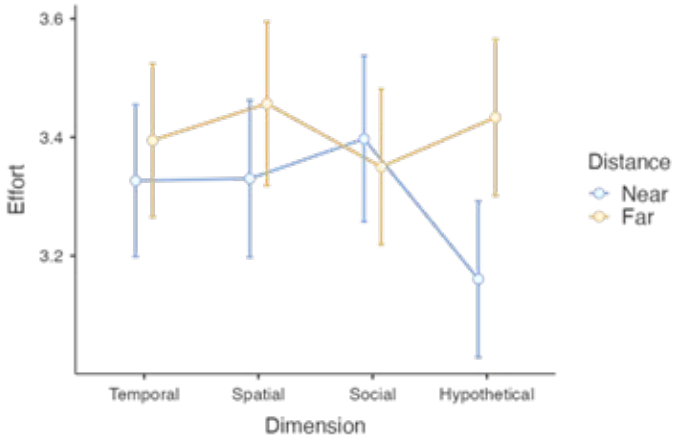

Figure 1: *Effort scores as a function of the interaction between distance and dimension. Error bars represent standard errors.*

We had predicted that construal level and distance would interact to influence the experience of mental effort, but the interaction term was non-significant, $F(1, 156) = 0.04$, $p = .834$. Although participants did report expending more effort to visualize distant (versus near) events in concrete terms, $t(156) = 2.83$, $p = .027$, they did not report expending more effort to visualize near (versus distant) events in abstract terms. Similar to the concrete condition, participants reported experiencing more effort when pondering near versus distant events, $t(156) = 2.68$, $p = .040$.

DISCUSSION

One experiment tested the mental effort involved in different types of mental construal. More specifically, we asked participants to visualize scenarios that varied in terms of psychological distance, level of construal, and dimension. The results indicated that all three variables impacted subjective feelings of mental effort, although not always in the manner we had expected.

First, the psychological distance implied by a scenario influenced how effortful it was to visualize. Specifically, far scenarios were perceived as more effortful to construe than near scenarios. This finding is consistent with expectations insofar as near scenarios are more familiar and tangible than far scenarios. Near events could be perceived as more tangible because individuals do not need to engage in as much construal to visualize them. On the other hand, distant events require individuals to extrapolate potential outcomes, which could be more challenging as they lack immediate reference points from current events. This perceived difference in effort in relation to psychological distance could influence how individuals perceive and interpret events, possibly affecting their decision-making processes and priorities; however, this speculation requires further testing.

Second, the subjective experience of mental effort was influenced by the level of construal applied to a scenario such that concrete construals felt more effortful than abstract construals. This result also corresponds with expectations insofar as more abstract construals tend to be the automatic or default mental mode. Default modes or automatic tendencies tend to be easier and less effortful than less automatic, more controlled modes.[6] These results are also consistent with the idea that describing events in more concrete detail requires greater effort.

> “WE FOUND UNEXPECTED DIFFERENCES IN MENTAL EFFORT BASED ON THE DIMENSION OF THE PSYCHOLOGICAL DISTANCE PARTICIPANTS VISUALIZED”

Third, we found unexpected differences in mental effort based on the dimension of the psychological distance participants visualized. Hypotheticalities were less effortful for participants to visualize relative to the temporal, spatial, and social dimensions. A possible explanation for this pattern pertains to the nature of hypothetical construal. Thinking in hypotheticalities is a common mental activity. Hypothetical scenarios are a crucial aspect of decisions that involve multiple possible outcomes.[7] Individuals must make multiple decisions every day, such as what clothes to wear, what food to eat, or what to say to a colleague, and it may be that the sheer number of decisions a person makes each day affords opportunities to think through hypothetical scenarios. If one thinks of hypotheticals often, then perhaps this type of thought becomes less effortful. Future research could test this speculation by relating the frequency of hypothetical thinking to the subjective experience of effort when construing hypothetical scenarios.

We also found that psychological distance and dimension interacted to influence feelings of mental effort. More specifically, the far hypothetical scenarios were more effortful to construe than near hypotheticals, but the near versus far difference did not hold for the other dimensions. This unexpected pattern suggests that hypotheticality may be a relatively unique dimension. Hypotheticality represents a combination of some, or all, of the other dimensions, and hence, may contain features or elements that exceed what any one dimension contains.

We had predicted that distance and construal level would interact to influence feelings of effort, but we found no evidence for this pattern. We reasoned that because individuals have a habitual tendency to think in more concrete terms about near events and in more abstract terms about distant events, construing scenarios in these terms would be relatively easy. We found some evidence for the former prediction but not the latter. Put differently, both concrete and abstract construals grew more difficult as distance increased. Even though abstract scenarios were less effortful to construe than concrete scenarios, the abstract scenarios were still more effortful to construe at far psychological distances (whereas we had expected far events to be easier to construe abstractly).

All studies have limitations. Regarding the current study, the possibility exists that the results we observed would not generalize to other groups of people. Our sample consisted of university students of a finite age range. Perhaps older adults or individuals who do not attend college would show different results. It is also possible that participants did not fully understand the tasks we asked them to do. Examples were provided for how to correctly respond to prompts, but we have yet to directly assess individual responses to the scenarios to verify compliance with task instructions.

We suggest that future studies use Semin and Feilder's Linguistic Category Model to assess the level of abstractness of responses.[8] This tool would allow for a more thorough understanding of the extent to which participants understood and complied with the task instructions. A more diverse sample could help rule out potential confounding variables, such as age or stage of life. Future studies could also feature different scenarios from the ones created for this experiment to test if the current findings generalize to other events.

CONCLUSION

This study tested for the first time the effort involved in construing events at different psychological distances. The results suggested that temporal, spatial, and social dimensions elicited similar levels of perceived effort, whereas hypothetical distance was less effortful to construe. Additionally, distant scenarios proved to be more challenging to visualize compared to proximal ones. Moreover, concrete construals required more effort than abstract ones, counter to our initial expectations. To our surprise, construal level and distance did not interact to influence effort.

This research represents a first step toward gaining a better understanding of the mental effort involved in different types of mental construal and scenario visualization. Insofar as individuals are disinclined to construe events concretely or to think about psychologically far events, this may be because those types of construals are more difficult than their more abstract or near counterparts. This could impact goal pursuit and performance. If a distant concrete goal is more effortful to construe, then it is possible that an individual may push off this goal pursuit because it is not worth the effort. Shedding light on likely barriers to goal pursuit may offer better direction for mitigating the effort costs of different types of mental construal.

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All other work conducted for the thesis was completed independently by the student.

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The Influence of Subcultures on Moral Foundations: Comparison between Westerners and Easterners in the United States

By Samika M. Sequeira ’26

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INTRODUCTION

What are morals? Morality, as defined by the American Psychological Association, encompasses a "system of beliefs or values relating to right conduct, against which behavior is judged to be acceptable or unacceptable."[1] In simpler terms, morals serve as the socially shared standard for appropriate behavior, although individual interpretations of morality may vary.[2] If an individual does not understand the morals of others, they may struggle to anticipate others' actions or determine how to behave themselves. This may impede social interactions, and, on a larger scale, society may not operate properly without a shared sense of morality. Additionally, social scientists have established a functionalist approach to morality, stating that morals are essential for society to function properly (Leach, Bilali, and Pagliaro, *Groups and Morality,* 123-149). Since social relations, a fundamental part of society, need common ground to operate, society may lose its foundation without morals. Therefore, morals serve as a collective code that people in society are expected to abide by, and without them, individuals in society would lack the common foundation essential for supporting their relationships with each other, ultimately causing the potential decline of society.

Moral Foundations Theory

The Moral Foundations Theory (MFT) was developed by researchers Haidt and Graham to address the development and cultural variability of moral values.[3] They established five moral foundations that can be grouped into two broader categories: individualizing and binding moral foundations.

Individualizing moral foundations, which emphasize self-focused concerns, include the values of harm/care and fairness/reciprocity. On the other hand, binding moral foundations emphasize larger groups and institutions and encompass the values of ingroup/loyalty, authority/respect, and purity/sanctity (Graham et al., *Mapping the Moral Domain,* 366-85). Haidt and Graham conducted surveys across different countries to address these variations in moral values cross-culturally (Graham et al., *Mapping the Moral Domain,* 366-85). While the majority of participants came from the U.S., Canada, U.K., and

"MORALS SERVE AS A COLLECTIVE CODE THAT PEOPLE IN SOCIETY ARE EXPECTED TO ABIDE BY"

Australia, the eight other major locations included areas such as East Asia and the Middle East. Even though the participants were largely from Western nations, the researchers concluded that the Moral Foundations Questionnaire (MFQ), used to assess moral foundations, was not necessarily biased towards Westerners due to a reasonable model fit and could therefore be administered across different cultures. They also noted that the interpretation of moral foundations may vary across cultures based on their belief and value systems. For instance, some cultures may interpret moral foundations in a more self-serving manner, while other cultures may interpret moral foundations in terms of their social group.[4]

Harm/Care

The moral foundation of care relates to the potential to feel compassion in response to seeing others' suffering (Haidt and Graham, *When Morality Opposes Justice,* 98-116). The harm/care moral foundation also involves feeling approval towards those who prevent harm. In terms of evolutionary history, mothers across various species have typically been sensitive to indicators of suffering in their offspring (Haidt and Graham, *When Morality Opposes Justice,* 98-116). In human relationships, this sensitivity extends to feeling compassion towards any being experiencing suffering, regardless of their relation to them.

Fairness/Reciprocity

The moral foundation of fairness describes helping behaviors that result from reciprocal actions (Haidt and Graham, *When Morality Opposes Justice,* 98-116). This foundation stems from a long history of cooperating and forming alliances with others, which has cultivated emotions, such as anger and gratitude, that encourage reciprocal interactions such as helping others.[5] The extent of this foundation depends on the cultural context. In some cultures, reciprocal interactions may conversely emphasize equality and individual rights instead of the expected desire to help others. The fairness/reciprocity moral foundation is relatively universal.

Ingroup/Loyalty

The moral foundation of ingroup pertains to one's loyalty and connection to their group (Haidt and Graham, *When Morality Opposes Justice,* 98-116). This foundation has developed from a history of living in groups for both humans and other species (Haidt and Graham, *When Morality Opposes Justice,* 98-116). Since individuals typically value their ingroup, they also value those who make sacrifices for the ingroup. On the other hand, people tend to dislike those who fail to help their group or those who challenge their group's values (Haidt and Graham, *When Morality Opposes Justice,* 98-116).

Authority/Respect

The moral foundation of authority describes the respect that one may hold for those in positions of power (Haidt and Graham, *When Morality Opposes Justice,* 98-116). Commonly throughout history, living beings have organized themselves into hierarchically structured groups, contributing to the formation of values like respect, admiration, and awe towards those in power (Haidt and Graham, *When Morality Opposes Justice,* 98-116). Additionally, respect towards powerful figures in society may have cultivated values of subordination, such as duty and obedience, that relate to this foundation (Haidt and Graham, *When Morality Opposes Justice,* 98-116).

Purity/Sanctity

The moral foundation of purity relates to self-improvement and spirituality.[6] Over time, humans developed the emotion of disgust which contributed to this foundation (Haidt and Graham, *When Morality Opposes Justice,* 98-116). Disgust can be a functional emotion, serving as a protective mechanism but can also be a social emotion. For example, disgust can protect people from transmittable diseases, but can also be shown towards those of a lower status, such as members of a lower caste performing undesirable tasks like cleaning and removing corpses. In some cultures, disgust can be associated with religious beliefs, leading to disdain for those driven by physical pleasures and selfish emotions like greed, lust, and gluttony. On the contrary, individuals who exhibit self-control over their desires may be perceived as spiritual or chaste, synonymous with purity.[7]

Morals and Culture

Previous moral research has primarily focused on differences between larger categories such as Western and Eastern countries. Generally, research has found that Western countries are more self-oriented and tend to prioritize individual beliefs when it comes to care and fairness, rather than prioritizing their relationships with others or their role in society.[8] This is similar to the MFT's individualizing foundations of care and fairness (Lomas et al., *Complexifying Individualism Versus Collectivism,* 61-89). Conversely, Eastern moral values may center around collectivistic principles, such as adhering to the group's values or moral code.[9] For example, Indians believe in dharma, which emphasizes the collectivistic concept of taking care of others, and a duty-based moral code in interpersonal relationships. This means that their morals are influenced by their role and connection to others in their group (Miller, *Cultural Diversity in the Morality of Caring,* 3-39). This is similar to the binding moral foundations of purity and ingroup, in that Indians may base their moral values on their religious beliefs, such as dharma, and their loyalty to their community. The emphasis placed on the community by Eastern ethnic groups is also similar to the authority foundation as well as the other binding foundations. Furthermore, research on subcultures in China found that Tibetans scored higher on care and fairness than Han and Uyghur, while Uyghur scored higher on loyalty, authority, and purity, demonstrating that differences in moral foundations across subcultures may exist in addition to cross-cultural differences.[10]

Generally, Westerners are higher in individualizing moral foundations, and Easterners are higher in binding foundations (Graham et al., *Mapping the Moral Domain,* 366-85). Some research has shown that individuals within subcultures differ on moral foundations (Du, *Validation of the Moral Foundations Questionnaire,* 1-11). This study adds to the literature by examining differences between Westerners and Easterners living in the U.S. Many of the studies exploring differences in moral values using culture were disproportionately based on more developed Western areas, such as the U.S. and the U.K., compared to lesser-developed Eastern areas such as South Asia and East Asia (Graham et al., *Mapping the Moral Domain,* 366-85). Therefore, the goal of this study is to explore the diverse range of subcultures in the U.S. based on the MFT.

Current Study

My goal is to investigate how the moral foundations of different cultural groups may be influenced by their different levels of individualism and collectivism based on their cultural backgrounds. Previous research suggests that Western cultures prioritize the self (individualism or independence), while Eastern cultures emphasize interdependent values and collectivism fairness (Lomas et al., *Complexifying Individualism Versus Collectivism,* 61-89). These differences in culture—individualism compared to collectivism—may extend to their moral values. Individualism is linked to individualistic moral foundations since they could both stress the self, while collectivism is linked to binding moral foundations since they both stress the group. While prior research compared people from geographically distinct Western or Eastern regions, the current study goes further by comparing Western and Eastern cultural groups within the U.S. It was hypothesized that groups influenced by Western culture, such as the White ethnic group, would exhibit higher levels of individualizing moral foundations compared to those with Eastern influences (H1). Additionally, it was predicted that groups primarily influenced by Eastern cultures, such as the South Asian, Southeast Asian, and East Asian groups, would exhibit higher levels of binding moral foundations compared to those with Western influences (H2).

METHODS

Design

The data was collected in a previous study conducted by my advisor, Dr. Heather Lench, with Minyoung Choi, Dr. Melissa Karnaze, and Dr. Linda Levine. The study explored the relationship between partisanship, general life satisfaction, and beliefs in the functionality of emotions.[11] This study utilized a 2 (Culture: Westerner vs. Easterner) between-subjects design that assessed differences in moral foundations.

Participants

The study included a total of 4,720 participants who were mostly female undergraduates (78%), while male (19%), trans male (0.3%), trans female (1%), genderqueer (1.4%), and non-binary (0.3%) undergraduates made up the minority. The participants were from Texas A&M University and the University of California, and they generally were young adults (M = 20.38, SD = 3.02). Participants were categorized into subcultures based on their previous responses on ethnicity and race. White individuals were coded as Westerners (N = 2,032), while South Asian, Southeast Asian, and East Asian individuals were coded as Easterners (N = 2,688). Individuals who did not fit into either of these categories, such as African Americans and Latinx individuals, were excluded from the original sample (N = 8,688).

Moral Foundations Questionnaire (MFQ)

The previous study administered the 20-item Moral Foundations Questionnaire (MFQ20) to assess participants' levels of different moral foundations (Graham et al., *Mapping the Moral Domain,* 366-85). The questionnaire consisted of 20 questions that were divided into two parts. Part one assessed the relevance of different moral concerns, including the five moral foundations, to one's moral judgments using a 6-point Likert scale from 0 (*not at all relevant)* to 5 (*extremely relevant).* In part two, participants were asked to express their agreement or disagreement with statements designed to elicit different moral values or foundations. Part two was scored on a 7-point Likert scale from 1 (*strongly disagree)* to 7 (*strongly*

agree). Higher scores on both scales indicated a higher endorsement of a specific moral foundation.

In terms of the broader moral categories, eight items measured individualizing foundations (α = .77), while 12 items measured binding foundations (α = .83). The five moral foundations were assessed by four questions each: harm/care (e.g., "Compassion for those who are suffering is the most crucial virtue," α = .59), fairness/reciprocity (e.g., "When the government makes laws, the number one principle should be ensuring that everyone is treated fairly," α = .65), ingroup/loyalty (e.g., "People should be loyal to their family members, even when they have done something wrong," α = .67), authority/respect (e.g., "Respect for authority is something all children need to learn," α = .64), and purity/sanctity (e.g., "People should not do things that are disgusting, even if no one is harmed," α = .66). Scales were formed by averaging scores across relevant questions for specific foundations.

Procedure

Online questionnaires were administered to gather responses from participants between October 22, 2020, and November 2, 2020. Secondary analyses were conducted on a subset of the original data focusing on different ethnic and racial groups.

RESULTS

Data Analyses

Independent t-tests were run using a statistical software program, SPSS version 29.0.0.0, on a subset of data obtained from a previously published study (Choi et al., *Do Liberals Value Emotion More than Conservatives?,* 364-380). These analyses compared Westerners and Easterners in terms of individualizing, binding, and the five foundations of harm/care, fairness/reciprocity, authority/respect, loyalty/ingroup, and sanctity/purity. For clarification, *M* measures the average value, *SD* measures the variance around the average, Welsh's *t* and *t* indicate the t-test score, and *p* measures the significance of the t-test score.

Moral Foundations

The study found that there are differences in individualizing foundations between Westerners and Easterners; Welsh's $t(4038.41) = 2.85$, $p = .002$. Contrary to the hypotheses, the results showed that Easterners ($M = 4.61$, $SD = 0.71$) scored higher on individualizing foundations than Westerners ($M = 4.55$, $SD = 0.79$, **Figure 1**). However, there was no statistical difference between Westerners ($M = 3.13$, $SD = 1.04$) and Easterners ($M = 3.16$, $SD = 0.80$) in the binding foundations; Welsh's $t(3596.05) = 1.20$, $p = .115$. Overall, the results indicate that while Easterners score higher on individualizing foundations, there is no variation in binding moral foundations between the two groups.

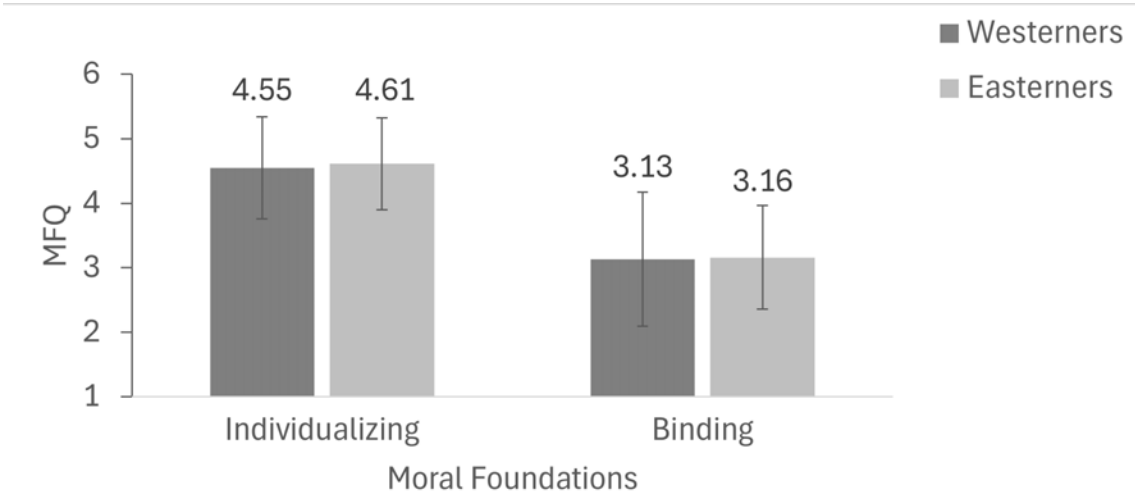

Figure 1. *Westerners vs. Easterners on Individualizing and Binding Moral Foundations.*

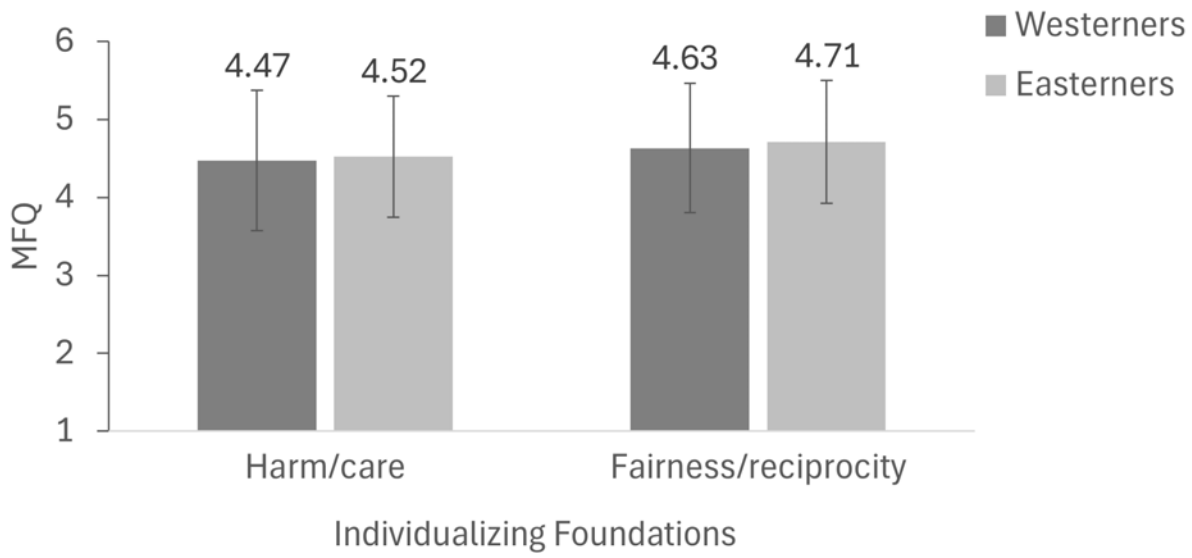

Figure 2. *Westerners vs. Easterners on Individualizing Moral Foundations (Harm/care and Fairness/reciprocity).*

Individualizing Moral Foundations

Easterners (M = 4.52, SD = 0.78) scored higher on the harm/care foundation than Westerners (M = 4.47, SD = 0.90); Welsh's $t(3934.24) = 2.06$, $p = .02$ (**Figure 2**). Similarly, Easterners (M = 4.71, SD = 0.79) scored higher on the fairness/reciprocity foundation than Westerners (M = 4.63, SD = 0.83); $t(4686) = 3.18$, $p < .001$. These results indicate that Easterners scored higher on the individualizing moral foundations of care and fairness.

Binding Moral Foundations

The study found that Easterners scored higher on the purity/sanctity foundation (M = 3.57, SD = 1.00) than Westerners (M = 3.23, SD = 1.13); Welsh's $t(3959.02) = 10.64$, $p < .001$ (**Figure 3**). On the contrary, the results showed lower levels of the other binding foundations. The loyalty/ingroup foundation was lower in Easterners (M = 2.85, SD = 1.01) than Westerners (M = 3.00, SD = 1.24); Welsh's $t(3768.13) = -4.56$, $p < .001$. Likewise, Easterners (M = 2.85, SD = 1.01) scored lower on the authority/respect foundation than Westerners (M

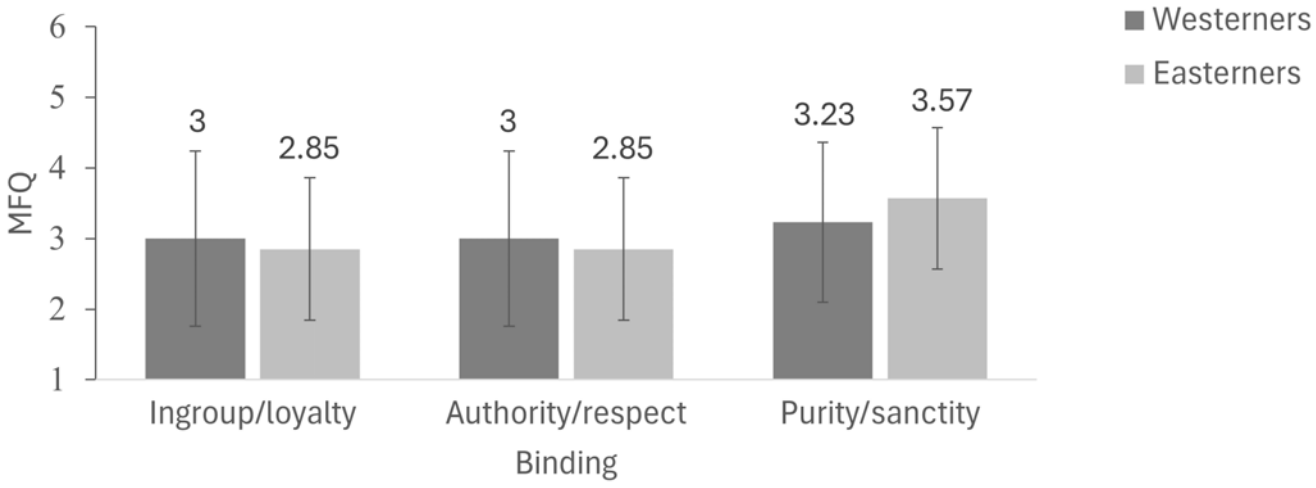

Figure 3. *Westerners vs. Easterners on Binding Moral Foundations (Ingroup/loyalty, Authority/respect, Purity/sanctity).*

= 3.00, *SD* = 1.24); Welsh's $t(3768.13) = -4.56$, $p < .001$. Overall, Easterners exhibit higher levels of individualizing moral foundations and only exhibit higher levels on the binding moral foundation of purity.

CONCLUSION

The goal of this study was to explore cultural differences in moral values (individualizing, binding, harm/care, fairness/reciprocity, ingroup/loyalty, authority/respect, and purity/sanctity foundations) between American subcultures (Westerners vs. Easterners). Contrary to Hypothesis 1, results indicated that Easterners scored higher on individualizing foundations than Westerners. While this is surprising, this finding overlaps with previous research findings indicating higher levels of the individualizing foundations of care and fairness in Eastern cultures such as South Asia, Southeast Asia, and East Asia (Graham et al., *Mapping the Moral Domain,* 366-85). Higher individualizing foundations in Easterners may be attributed to assimilation and westernization. For instance, Indian adolescents feel pressure to assimilate into the culture of their host country.[12] Furthermore, due to the acculturation of Western norms, Chinese Americans decreasingly use Traditional Chinese Medicine.[13] Similarly, first-generation and second-generation Chinese Canadians exhibit Western preferences and ideologies for food, nutrition, and health.[14] This gradual transition towards Western values among Easterners, such as Indian and Chinese immigrants, may help them better adapt and form relationships in their new environment. Therefore, this change can lead to higher levels of individualizing moral foundations for Easterners such as those found in the current study.

Contrary to Hypothesis 2, the study revealed no significant difference in binding foundations between Westerners and Easterners. However, while Easterners scored lower on the binding foundations of ingroup and authority, they scored higher on the binding foundation of purity. This conflicting finding partially aligns with earlier research, which found higher levels of purity in Eastern cultures, while also finding higher levels of the other binding foundations (ingroup and authority) in Eastern cultures compared to Western cultures (Graham et al., *Mapping the Moral Domain,* 366-85). Since the current study's findings are relatively novel in that they do not completely align with previous research, it is important to further study cultural differences in moral foundations, namely the Westerners vs. Easterners distinction.

Limitations and Future Directions

There was little control over the variables since the data was from a previous study, which contributed to some limitations. The sample was from the University of California and Texas A&M University, limiting the scope of the study. This limitation makes it difficult to generalize results about American subcultures to the entire U.S. since participants were from universities from only two states. Additionally, the current study did not account for the duration of time spent by participants in the U.S., which could be important to understanding the extent of cultural influence. Furthermore, since the sample was mostly female and young adults, the findings may not be entirely representative of the population of the U.S., making it harder to generalize results.

Future studies could investigate moral foundations of biracial individuals in the U.S., specifically those of both White and Asian descent. This may yield interesting results as these individuals would have influences that shape their identity from both Western and Eastern cultures, while primarily being part of a Western environment such as the U.S. Overall, this could allow researchers to assess how moral foundations may be affected by varying influences of Western and Eastern cultures in an individual. Additionally, studies could also explore the effects of these subcultures on one's personal identity compared to their surrounding social environment. Despite the present study including a significant number of multiracial individuals, further exploration might be challenging as ethnic and racial groups were not deliberate variables, resulting in an uneven distribution of multiracial individuals.

Given the significant impact of social structures on individuals, it is important to include samples of minorities that are typically excluded from research to understand individual differences across cultures and to encourage social scientists to be more inclusive.[15] Although the participants from the data that I analyzed were all from American universities (University of California and Texas A&M University), I believe that they still relate to

the application of my study, as the Eastern group (operationalized as South Asian, Southeast Asian and East Asian) are ethnic minorities in the United States. Ethnic minorities are predicted to constitute over 50 percent of the United States population by 2044 (Yang et al., *Factors Underlying Beliefs of Traditional Chinese Medicine Efficacy,* 207-10). These ethnic minorities may be impacted by assimilation, which may explain the higher endorsement of individualizing foundations, typically found in Western cultures and in Easterners in the U.S. Therefore, it is valuable to examine these ethnic minority groups and identify certain gaps between the Moral Foundations Theory and its potential limitations in accommodating these cultural minorities that make up such a substantial proportion of the American population.

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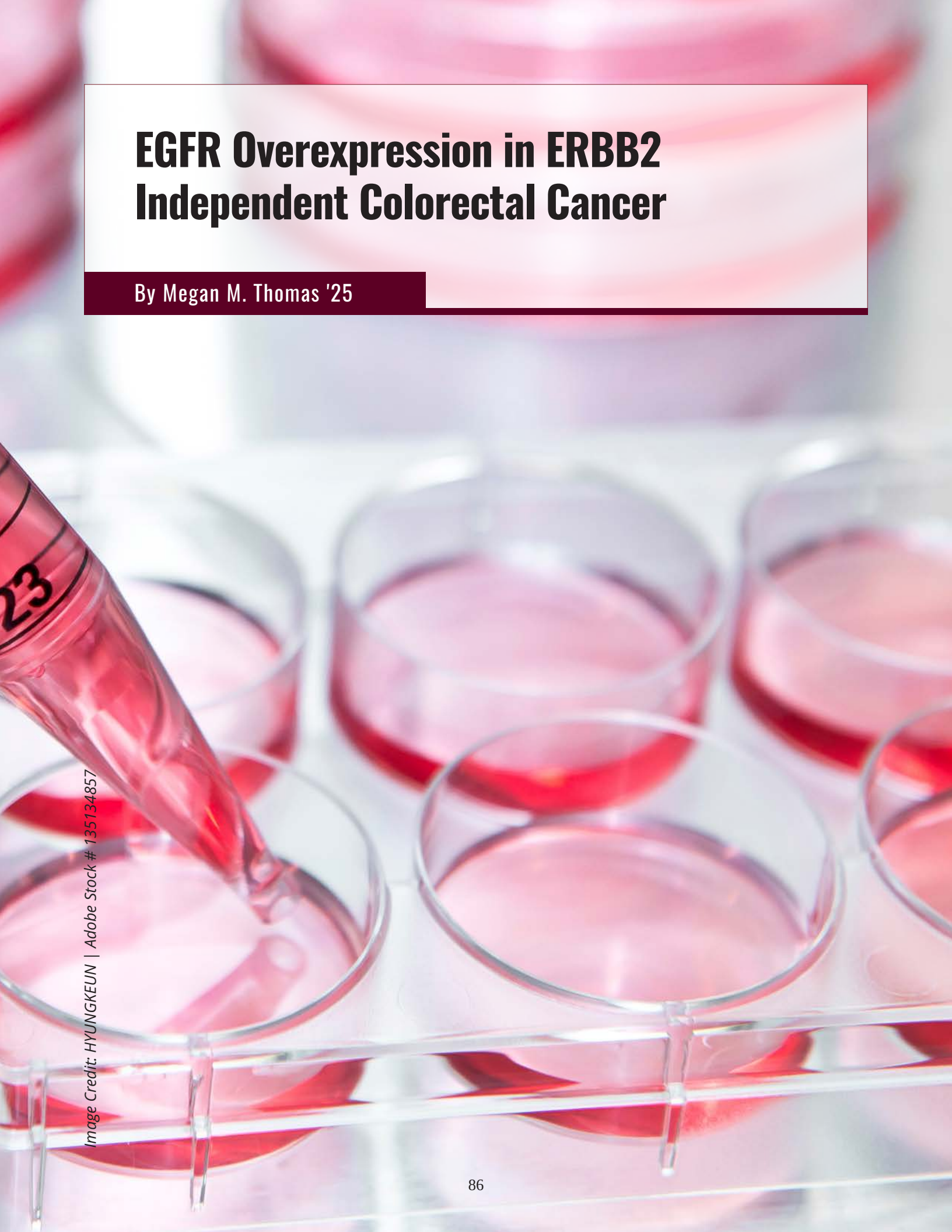
EGFR Overexpression in ERBB2 Independent Colorectal Cancer

By Megan M. Thomas '25



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INTRODUCTION

Importance of Genetic Background in CRC

Colorectal cancer (CRC) is the third most common malignancy on a global scale.[1] Moreover, it is the second leading cause of cancer-related deaths in the United States, with over 150,000 new cases estimated in 2023. Many polyps or tumors associated with CRC may be missed when doing routine colonoscopies or screenings or from a lack of screenings, in general. Through this missed screening, the tumors may become malignant and progress rapidly before the next possible screening. Thus, it is important to identify genetic markers that could predispose an individual to the diagnosis, progression, and metastasis of CRC. By identifying this genetic background, preventative clinical therapies may be administered to improve the livelihood of patients.

This research project is focused on the genetic background associated with EGFR and ERBB2. Epidermal growth factor receptor (EGFR) is a cell surface receptor that requires the binding of extracellular molecules to be activated. This stimulates many downstream signaling pathways involved in cell proliferation and forming new blood vessels through angiogenesis.[2] These functions are critical for cancer cell survival, marking EGFR as a viable target for CRC metastasis. Additionally, erythroblastic oncogene B (ERBB2) also falls under the EGF family of receptors. It does not bind ligands directly but rather, forms a complex with other EGF receptor kinases to stabilize and enhance activation of downstream signaling pathways associated with cell proliferation. In CRC, ERBB2 serves as a negative predictive biomarker.

> **"THROUGH THIS MISSED SCREENING, THE TUMORS MAY BECOME MALIGNANT AND PROGRESS RAPIDLY BEFORE THE NEXT POSSIBLE SCREENING."**

This research analyzes how EGFR and ERBB2 expression as well as activity contribute to CRC and its viability to be used as a target for clinical therapies.

Previous Research

Previous research has implied that in an ERBB2 independent CRC model, fewer tumors develop, but are ultimately larger in size. More polyps in ERBB2 independent intestinal tissue are larger than one millimeter as compared to polyps in the control ERBB2 dependent intestinal tissue. It was suspected that this increase in size is associated with compensatory EGFR overexpression (**Figure 1**).

Through prior research investigating signaling pathways and genes, it has also been discovered that the genes associated with the EGFR signaling pathway are upregulated in ERBB2 deficient murine colon tissue. This

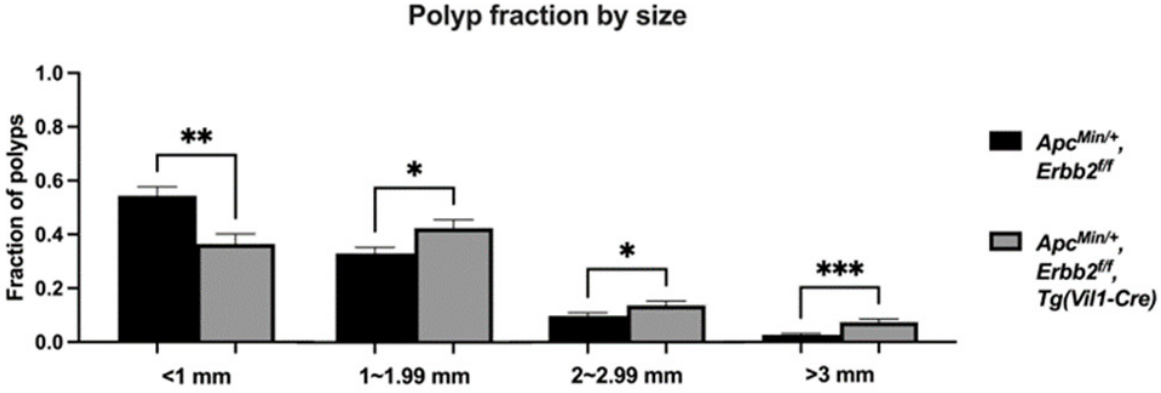

Figure 1. *Intestinal Polyp Quantification in ERBB2 Independent and Littermate Control Tissue*

indicates a potential direct relationship between EGFR upregulation and ERBB2 deficient tumors. Analysis of the two primary downstream signaling pathways suggests that if EGFR is overexpressed, these downstream pathways will be continuously activated, increasing cell division and survival, leading to a more vigorous cancer phenotype (**Figure 2**). This may cause more severe symptoms related to CRC and a higher mortality rate.

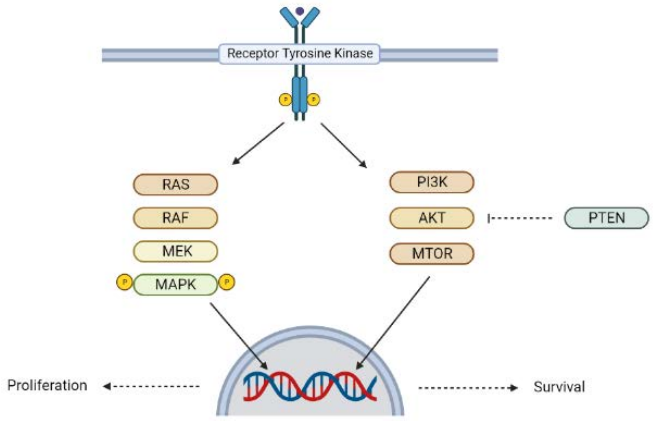

Figure 2. *EGFR Downstream Signaling Pathways*

Additionally, the transcription analysis was able to detail differential gene regulation. A comparison of tumors and the adjacent normal tissue suggested that the oncogenic EGFR pathway is upregulated as well as the oncogenic MAPK pathway in ERBB2 deficient samples and that there is no significant change in EGFR signaling in these ERBB2 dependent samples.

These analyses indicate a potential direct relationship between EGFR upregulation and ERBB2 deficient tumor progression.

Research Objectives

It is important to understand the results from this previous research as it identifies a relationship between EGFR overexpression and ERBB2 deficiency, as well as how this may be associated with a more vigorous cancer phenotype. Thus, this relationship is a possible way to better personalize treatments for individuals with this genetic background that have been diagnosed with CRC.

The hypothesis that in ERBB2 deficient tumors, EGFR overexpression will be observed, and is indicated by high protein concentration levels associated with the EGFR signaling pathway and lower levels of cell death. This hypothesis was investigated by using EGFR antibodies along with ERBB2 deficient murine colon tissue samples to run a Western blot assay, which measures protein concentration levels. Additionally, an assay that measures cell death was used to compare tumors and adjacent normal tissue. It was expected that lower levels of cell death would be observed in ERBB2 independent tissue as there is more tumor-specific cell division. This may suggest that there is EGFR overexpression due to increased activation of downstream signaling pathways, leading to higher cell survival. These results may be analyzed to further examine the relationship between EGFR overexpression and ERBB2 deficiency.

METHODS

Isolating Samples

To obtain the samples, appropriate necropsy procedures were performed on laboratory murine specimens. This is a postmortem procedure to collect vital organs and tissue samples for further analysis.[3] Samples 1 and 2 had an *APCminERBB2$^{f/f}$CRE^{+}* genotype. The function of the APC gene is to act as a tumor suppressor that prevents uncontrolled cell growth. Specimens with a mutation in relation to the function of this gene develop multiple intestinal adenomas.[4] Cre-recombinase is a protein that is able to recognize DNA sites flanking the ERBB2 sequence to splice and delete it from the genome, effectively making the cells deficient in the ERBB2 gene. Samples 1 and 2 were considered to be the knockout samples, representing ERBB2 independent tumors. Samples 3 and 4 had an *APCminERBB2$^{f/f}$* genotype. The absence of the Cre-recombinase protein maintains the presence of the ERBB2 gene in the murine genome. Samples 3 and 4 were considered to be the control samples, representing ERBB2 dependent samples. For each specimen, the tumor and normal adjacent tissue were separated and analyzed.

Western Blot Assay

To perform the Western blot assay, protein was first isolated from the samples. The cells and tissues in the sample were lysed using a buffer. The samples were then homogenized and centrifuged to isolate the protein

from the remaining cellular debris. This isolated protein was used in a subsequent assay to standardize total protein concentration levels in all the samples. Next, all samples were run on a gel for size separation before being incubated with primary and secondary antibody solutions to be imaged and quantified for EGFR protein concentration levels.

Cell Death Assay

To perform the assay, thin sections of the samples were first deparaffinized and rehydrated to remove the paraffin wax and allow the tissue to take up water from its environment. The samples were then blocked with primary antibody and detection reagent solutions. Next, the slides were dehydrated, stained, and mounted to be observed under the microscope. Positively stained cells were quantified, and results were recorded.

RESULTS

Western Blot Assay

Western blot of EGFR protein showed that in ERBB2 independent murine colon tissue samples, there was more EGFR protein as compared to ERBB2 dependent murine colon tissue samples (**Figure 3**). This directly supports the preliminary hypothesis that EGFR is overexpressed and thus upregulated in the ERBB2 independent CRC model.

Cell Death Assay

Initially, from a visual standpoint, it can be observed that there were more positively stained cells in the control tissue as compared to the ERBB2 independent colon tumor samples (**Figure 4**). This suggests that there were more dying cells in the littermate control than the experimental tissue (**Figure 5**).

This was further supported through quantification (**Figure 6**). The results from this assay confirmed that in ERBB2 independent colon tissue, there were lower levels of cell death, indicating that cells were better able to multiply and survive. This may be in part due to the increased activation of downstream EGFR signaling pathways. This also directly supports the preliminary hypothesis that EGFR is upregulated in the ERBB2 independent CRC model.

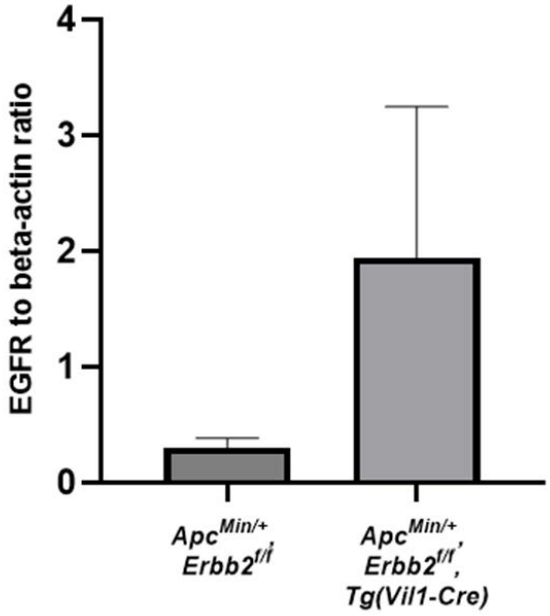

Figure 3. *Relative EGFR Protein Levels in ERBB2 Independent and Littermate Control Tissue*

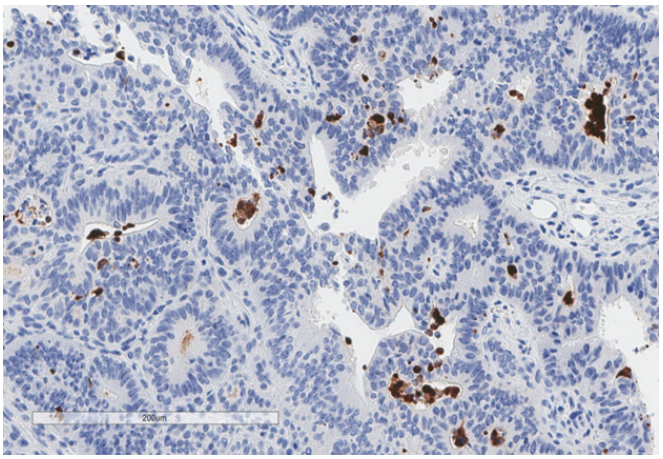

Figure 4. *Cell Death Assay of Littermate Control Colon Tumor Tissue*

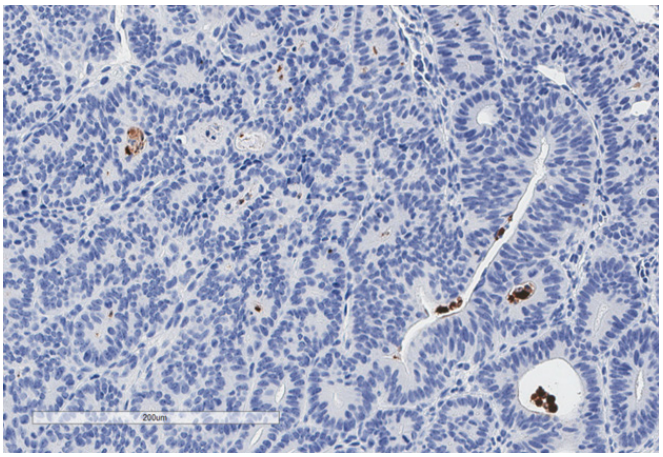

Figure 5. *Cell Death Assay of ERBB2 Independent Colon Tumor Tissue*

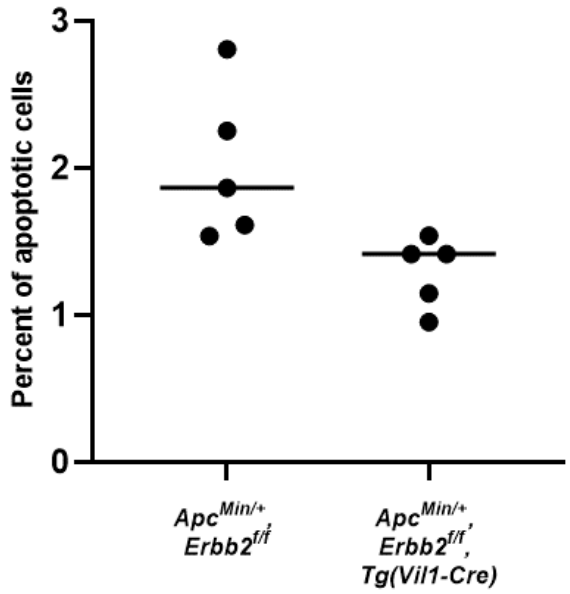

Figure 6. *Cell Death Levels in ERBB2 Independent and Littermate Control Tissue*

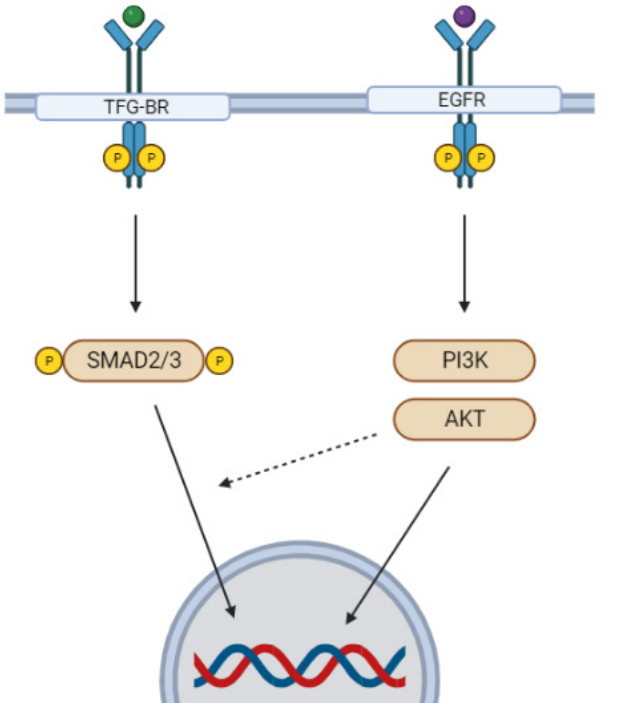

Figure 7. *TGF-β and EGFR Signaling Pathways Crosstalk Interactions*

CONCLUSION

Overall Results

Preliminary research has shown that in ERBB2 independent CRC, there are fewer tumors, but these are larger in size. This has been predicted to be due to the compensatory upregulation of EGFR. Additionally, previous pathways and gene analyses have indicated the increased activation of pathways associated with EGFR that are linked with cell proliferation and survival. Thus, in ERBB2 independent CRC, there is overexpression of EGFR. In this study, the interactions between EGFR and ERBB2 were further investigated. The objective of this research project was to characterize EGFR overexpression in ERBB2 independent murine colon tissue. To do this, murine colon tissue samples were used to conduct a traditional Western blot assay. Additionally, an assay was used to directly measure levels of cell death. From these results, EGFR protein levels, as well as cell death levels, were analyzed and provided further evidence for the potential relationship between EGFR overexpression and ERBB2 deficiency. Both the higher EGFR protein concentration levels and the lower amounts of cell death in the ERBB2 independent samples indicate a direct relationship between EGFR upregulation and ERBB2 independent tumor progression resulting in a more vigorous resulting cancer phenotype.

Future Directions

To further elucidate the relationship between EGFR overexpression and ERBB2 independent CRC, additional Western blot assays can be performed to compare levels of phospo-EGFR protein concentration levels in ERBB2 independent and littermate control tissue. This phosphorylated tag will show the levels of EGFR activation in these samples. It is predicted that this assay will continue to support the preliminary hypothesis by demonstrating higher levels of activated EGFR protein concentrations in the ERBB2 independent murine colon tissue samples.

Furthermore, proliferation assays may be conducted to directly compare levels of proliferation in ERBB2 independent and littermate control tissue. From the current results, proliferation levels are inferred as a correlation with lower levels of cell death. By altering the assay to specifically measure proliferation, it may provide more direct and accurate results. It is predicted that this assay will also continue to support the preliminary hypothesis by demonstrating higher levels of proliferation in the ERBB2 independent murine colon tissue samples. As mentioned before, this could be a result of the upregulation of the gene signaling pathways associated with EGFR such as the MAPK and PI3K-AKT pathways that

directly lead to increased cell proliferation and survival. These are both important subsets for the progression of cancer.

Additionally, based on previous analysis, the activated TGF-β signaling and the inhibited immunoglobulin complex be further explored. There is potential crosstalk between the EGFR and TGF-β signaling pathways (**Figure 7**). Specifically, when TGF-β is activated, a process very similar to the EGFR signaling pathway is started. Therefore, from previous research and analysis, there are predicted interactions between these pathways. Thus, if EGFR is overexpressed, TGF-β may also be overexpressed and could possibly play a role in this CRC phenotype.

Clinical Implications

Understanding this relationship may allow for deeper knowledge regarding the genetic precursors that play a role in the progression of CRC. Many patients have shown little to no benefit from anti-EGFR treatments. This may be due in part to the role of ERBB2 in the overexpression of EGFR. Thus, clinical therapies can be adjusted and targeted to utilizing ERBB2 as a negative novel predictive biomarker. As a direct result, physicians may be able to better understand and personalize treatment to best care for the needs of patients with CRC.

As previously mentioned, CRC continues to play a debilitating role in the lives of many individuals, not only in the United States, but on a global scale, as well. Thus, by increasing the awareness and understanding of genetic factors that could predispose individuals to the diagnosis, progression, and metastasis of CRC, preventative and therapeutic clinical aids may be administered to save the lives of many. Thus, it is important to continue the investigation into these genetic markers and their corresponding relationship to CRC as it strives to make a direct impact on individuals in communities.

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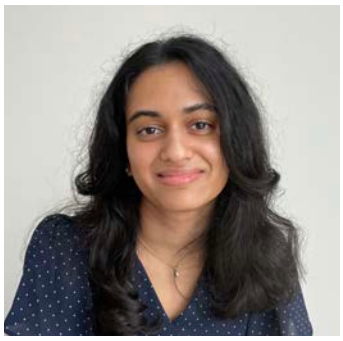

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