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ReCUR is now accepting submissions for the next issue from Honors College students and UURAF participants. Please visit our website at recur.msu.edu for more information.

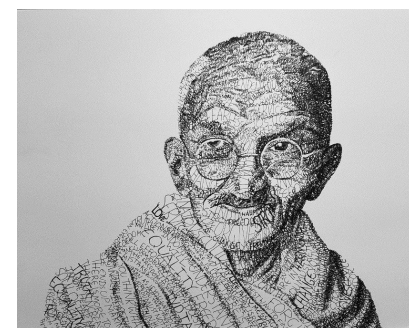
About the Cover

The Volume 8 cover of ReCUR is "The Butterfly Painting," a surrealist acrylic painting by Anusha Mamidipaka. Anusha is a third-year neuroscience and psychology student in the Michigan State University Honors College. The inspiration for this piece came from observing instruments as they painted a landscape complete with grass, water, and a house. By merging the realistic landscape with the more abstract dripping paint, this image is meant to invoke the wonder of nature. Anusha received 3rd place for the painting in the Honors College Art Contest in January 2019.

Honors College student drawings, painting, graphic designs and photography were reviewed by a committee of faculty, staff and students; the winning artwork is on display in Eustace-Cole Hall. First place was awarded to Hattie Pimentel, a third-year chemical engineering student in the Honors College, for her piece "Words of Mahatma Gandhi."



The Butterfly Painting
Anusha Mamidipaka



Words of Mahatma Gandhi
Hattie Pimentel

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About the Contributors

How Talker Rhythm Affects Speech Understanding in Noise

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Introduction

Communication in daily life rarely occurs in silence. Imagine you are enjoying a dinner out with your colleagues. As the restaurant fills and more conversations join the listening environment, you begin to have trouble hearing the story your friend is telling across the table. When you lean in and focus more on the story while trying to ignore the background talking, you are making conscious use of your speech-in-noise (SIN) ability. This ability to segregate target speech from background sounds is in many cases an unconscious effort; you employ it in every scenario that involves hearing the speech of another person while in a noisy environment. A considerable amount of research has assessed various aspects of SIN ability and has found that it varies greatly between individuals and is strongly affected by factors such as hearing acuity and age (Bronkhorst, 2000; Humes, 1988; Humes, 1996, Parbery-Clark, Strait, Anderson, Hittner, & Kraus, 2011). For the elderly and some pediatric populations, deficits in SIN ability can impede daily function and affect overall quality of life (Parbery-Clark et al., 2011; Ziegler, Pech-Georgel, George, Alario, & Lorenzi, 2005). Investigations to improve this ability (or at least counteract impairments) are therefore valuable for a significant portion of our population, and the first step in this process is advancing our fundamental understanding of how SIN ability works.

Current theory related to speech understanding in noise links perception with attention; research by Jones and Boltz (1989) provides the well-referenced Dynamic Attending Theory (DAT) to connect the two concepts. In the context of patterned stimuli such as speech, DAT posits that rhythms automatically entrain listener attention and direct it to rhythmically expected time points (Jones & Boltz, 1989). Rhythm plays an important part in how we perceive

and produce speech (Lykartsis, Lerch, & Weinzierl, 2015; Tierney & Kraus, 2015; Wieland, McAuley, Dille, & Chang, 2015). Given this relationship between rhythm and speech, the purpose of the present study was to examine the effect of talker rhythm on individual ability to perceive speech in difficult listening conditions.

Two experiments were conducted, each with an identical paradigm and different listening conditions. During the experiments, participants heard spoken sentences of the form “Ready [call sign] go to [color] [number] now,” where the target talker was identified by the call sign “Baron”. Sentences used in this study included eight different Call Signs (“Baron”, “Charlie”, “Eagle”, etc.), four different Colors (“Blue”, “Red”, “Green”, and “White”), and seven different Numbers (1-8, excluding 7 to limit all numbers to a single syllable). The target was presented either alone or amidst a background composed of two-talker babble or constant noise. The speech-shaped noise was set to -6 dB to match performance in the intact rhythm conditions with a two-talker babble background (based on pilot studies). The constant noise condition was implemented to determine whether the target-talker rhythm effect is due to less effective entrainment to the target speech or to attention being pulled by the more regular rhythm of the background speech.

Participants were instructed to listen for the target talker and report the color and number spoken by clicking on the corresponding box on the color-number grid; performance was determined by the proportion of correct colors and numbers reported. The rhythm of target and/or background talkers could be modulated as a continuous function of the standard auditory signal to produce varying degrees of arrhythmic speech; random segments of the signal would be alternately compressed and lengthened. This “rhythm variation” could be manipulated in

25% increments, whereby increasing percentage represents greater modulation and thus greater arrhythmicity. The alteration consisted of temporal expansion and contraction of portions of the sentences in a sinusoidal pattern. The rhythm alterations were realized using the Pitch Synchronous Overlap and Add (PSOLA) algorithm as implemented in Praat (e.g., Moulines & Charpentier, 1990). Building on DAT, we expected rhythmic (as opposed to arrhythmic) speech to entrain listeners' attention. Under this assumption, entrainment would facilitate the ability to track target speech in the difficult listening conditions conferred by the multi-talker/noisy background. As such, we made the following predictions: Prediction 1: Holding background rhythm constant, listener performance will decrease as a function of increasing target rhythm modulation. Prediction 2: Holding target rhythm constant, listener performance will increase as a function of increasing background rhythm modulation.

Methods

Participants consisted of 55 adults (mean age = 20.6 years; 21 male) recruited from Michigan State University and the surrounding area. Participants were native speakers of American English with normal hearing.

In Experiment 1, participants heard the target-talker presented amidst a two-talker background babble. The rhythm variation of the target or the background was held at 0% while the other was either 0%, 25%, 50%, or 75%. In Experiment 2, the target was presented either alone or amidst speech-shaped noise, and the rhythm variation of the target was again 0%, 25%, 50%, or 75%. On each of 640 trials, participants listened for the target talker, identified by the call sign "Baron", and reported the color and number spoken. Performance on the task is described as the mean proportion of reported colors and numbers that were correct, i.e. were actually spoken by the target talker.

Results

Figure 1 shows performance as a function of rhythm variation. Results from Experiment 1 indicate that while the background rhythm is held constant, each degree of increasing target rhythm variation reduced performance. Conversely, varying the background

rhythm while holding the target rhythm constant increased performance. Results from the target-only condition of Experiment 2 demonstrate that varying the target rhythm in isolation had no effect on performance; notably, rhythm variation did not affect speech comprehension. Additional results from Experiment 2 indicate that, with a background of constant noise, varying the target rhythm reduced performance to the same extent as the target-varied condition in Experiment 1.

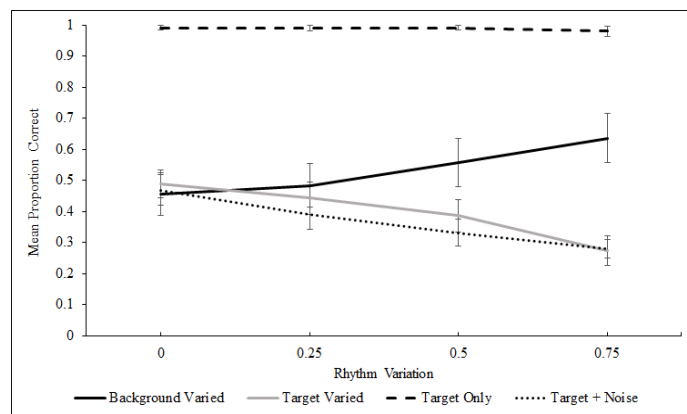


FIGURE 1. Performance in Experiment 1 (background-varied and target-varied conditions) and Experiment 2 (target-only and target+noise conditions).

Finally, a separate experiment compared two- and six-talker backgrounds and found that in both conditions varying the target rhythm significantly reduced performance, and varying the background rhythm significantly improved performance. All results were significant, $p < .001$.

Discussion

The results are consistent with DAT, which proposes that rhythm entrains attention and directs it to rhythmically expected time points. The performance trends support the hypothesis that rhythm creates expectations about when the target spoken color and number will occur. The results provide support for the view that the target-talker rhythm effect is due to less effective entrainment to the target speech rather than attention being drawn to (or entrained by) the more natural rhythm of the background speech. The rhythm of speech can be used to facilitate selective attention to one spoken message in the presence of competing speech and noise.

Additionally, these results add to an emerging body of work demonstrating the importance of talker

rhythm in understanding speech in difficult listening situations. Behavioral and neurophysiological evidence has shown neural entrainment to speech rhythms plays an important role in speech perception. Much of this work suggests that neural entrainment to speech rhythms is not a simple, passive, stimulus-driven entrainment process, but rather involves anticipation and active predictions of future events and incorporates hierarchical levels of temporal structure.

Future research will investigate a) differences in perception based on target gender, b) whether target rhythm affects perception in a background of talking and noise, and c) if rhythm confers a perceptual advantage in an open-set speech understanding paradigm as opposed to the present closed-set. In summary, the current study showed that rhythm has its influence by the degree to which it facilitates entrainment to the target sentence. Natural speech rhythm, with its quasi-periodic structure, is crucial for selective entrainment to speech under difficult listening conditions.

Acknowledgements

This research was made possible by the members of the Timing, Attention, and Perception laboratory, who devoted not only their time but an immense cognitive effort to this project. We are grateful for their dedication to science and their valuable insights. This project benefited greatly from the mentoring of J. Devin McAuley and comments received from Carolyn Kroger and Leigh VanHandel. The study could not have reached its full potential without their scholarly guidance. Financial support was provided by the National Institutes of Health research grant, R0104052.

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Robin Hood: Fact or Fiction

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Some children dream of becoming superheroes, dressing up in disguise and helping people in need. They read tales about vigilantes in modern day media. Perhaps they have even heard the story of the medieval legend, Robin Hood, and may wonder whether he actually existed. Research shows that the notion of Robin Hood stealing from the rich and giving to the poor is only a myth. However, his name may very well be real. There are many references to variations of the name throughout medieval English records; indeed, one name in particular, Robhood, is found in the 14th-century court rolls of Walsham Le Willows. This paper explores the possibility that Robhood may have been one of the pre-cursors to the name Robin Hood. Additionally, it is possible that names similar to Robhood were given to families as punishment for misbehaving.

This research furthers the understanding of the origins of Robin Hood. To know how it does, it is important to understand the origins and evolution of the story of Robin Hood. The first known literary mention of the name Robin Hood is in a poem called *Piers Plowman* by William Langland.¹ It was written in the 1370s. Robin Hood first became the subject of ballads around 1450, although at that time the tales limit his actions to stealing from the rich.² Stories of Robin Hood giving to the poor did not appear until the 16th century. It was around this time that the Robin Hood the world knows today was created. Over time, his backstory changed from one of modest origins to noble birth and other characters, such as Maid Marian, were added until his story evolved into the one known today.

While the first known publication of the name of Robin Hood was in the 1370s, the notion of him is much older. Professor J. C. Holt believes that his origin may be in the 13th century, relying on the name “Robynhod,” which appeared in a Sussex subsidy

role of 1296.³ His theory is supported by the discovery of another similar name. On or about April 21, 1262, a man named William Robehod was pardoned an amercement of one mark for seizing the chattels of a fugitive without a warrant.⁴ This event is insignificant except for the name. The name William Robehod appeared approximately 100 years before the publishing of *Piers Plowman*, making it one of the earliest, if not the earliest, reference to a precursor to the name Robin Hood. This research discovered another version of Robin Hood that pre-dates *Piers Plowman*, indicating that the name is older than previously believed.

Robhood, which is a family’s surname, is a variation of the name Robin Hood that appears approximately 50 years before the publication of *Piers Plowman*.⁵ The Robhood family lived in the village of Walsham Le Willows in the county of Suffolk, England.⁶ The Robhood family appears in the court rolls of Walsham Le Willows many times. (Court rolls are a set of records kept about a specific manor and the activities that occurred on the manor.) The most common information court rolls contain are fines against individuals in the manor. The first mention of the Robhood family in the court rolls of Walsham Le Willows is on August 9, 1317, although at the time their name was not Robhod, it was Fenner.

Alice the widow of William Fenner [le fenere] complains against Matthew Hereward [Therward] and Robert his brother, in a plea of dower, and they have a day until the next court etc., pledges for Alice William Hawys and Walter Rampolye.⁷

References to this complaint in later court records show that Fenner is an alias for Robhood; the family name was originally Fenner, but it was changed to Robhood. This is the earliest known reference to the

1. David Crook, “Some further Evidence Concerning the Dating of the Origins of the Legend of Robin Hood.” *English Historical Review* 99.392 (1984): 530.
2. Thomas Leitch, “Adaptations without sources: the Adventures of Robin Hood.” *Literature-Film Quarterly*, 36, no 1 (Jan, 2008).

3. Crook, “Further Evidence,” 530-531.
4. Crook, “Further Evidence,” 531.
5. Ray Lock, *The Court Rolls of Walsham Le Willows, 1303-50*. Suffolk: The Boydell Press, 1998.
6. Lock, *Court Rolls 1303-50*.
7. Lock, *Court Rolls 1303-50*, 56.

family. However, the family is older than that. Multiple times the court rolls refer to Alice Robhood being a widow to a man named William Robhood. For example, in the court rolls for October 11, 1317,

Robert Hereward [fined] 6d. because he unlawfully deprived Alice the widow of William Robhood of her rightful dower of the tenement, formerly held by William in bondage, viz. half a messuage la., of land; ordered the reeve and hayward to have her rightful dower delivered to Alice, following the verdict of the homage and the custom of the manor. Alice pays 6d. fine for entry, pledge Walter Rampolye.⁸

This entry suggests that the name Robhood was used to refer to this family even before this entry in the court rolls. It is even possible that the name could go back as far as the 13th century. The interesting part, though, is that the family's original name appears to have been Fenner and it later changed to Robhood. It is possible that the name was changed due to misbehavior of some family members. The court rolls give no explanation as to why the name change occurred.

The court rolls contain many entries for the Robhood family during the 14th century. It tracks what the family was doing and what their life was like. While individual people in the family seem to have been fined frequently, they appeared to live typical lives for the era. Most people in the family were villein farmers, meaning a person who is legally tied to land given to them by the lord of the court. As seen in the previous cited court roll, William Robhood was a villein farmer because he held land in bondage, meaning he was tied to this land. They tended to the land without causing major trouble, although one member of the family, Peter Robhood, does seem to be somewhat of a common malefactor. In his lifetime, he was amerced for over 397 d. This number is a minimum because at times the court rolls do not list how much he was fined. He had many run-ins with the lord of the manor. For example, the following entries appear in order in the court rolls on June 27, 1388,

Peter Robhood [fined] 40d. because he broke the lord's impounding (?pundagium) of three

horses, taken by the reeve for various trespasses against the lord.

The same Peter [fined] 12d. because he went to the lord's fold and took away from there 39 sheep of his own property without leave, and delivered [illeg].

The same Peter [fined] 40d. because he broke the lord's impounding, namely \outside/ the lord's fold, at another time, without the (?alibi) of the reeve, and he took and removed (?elongavit) 112 ewes far outside the lord's domain, to the lord's grave loss.

The same Peter in mercy because as a result of the aforesaid trespass, the lord lost 13 unshorn hoggets, valued at 12d. each, 13s. in total, which [damaged]; \condoned by the lord/.

The same Peter Robhood [fined] 20s. \and John Hawys 8s./ because they eloigned John Clement, the lord's shepherd and keeper of the cullet, on the morrow of Ascension Day [May 17] [damaged] Michelmas, and the lord lost dunging of eight acres of land, worth 2s. per acre; ordered [damaged].

The same Peter [fined] 3d. for damage in the lord's pasture at High Hall close with various beasts.

Peter Robhood [fined] 1d. for damage in the lord's wheat at High Hall with his sheep.⁹

These are not the only examples of Peter Robhood getting into trouble with the law. While this was the worst case for him and the most extensive, the record supports the picture of him as a miscreant.

Robin Hood is frequently described as a yeoman, and in many of the early stories he is seen as their equal. The problem with this is that the term yeoman has had many different meanings throughout history. In the sixteenth and seventeenth century, it referred to a person who was a wealthy peasant farmer.¹⁰ A

9. Ray Lock, *The Court Rolls of Walsham Le Willows, 1351-99*. Suffolk: The Boydell Press, 2002, 159.

10. Richard Almond, and A. J. Pollard. "The Yeomanry of Robin Hood and Social Terminology in Fifteenth-Century England." *Past & Present*, no. 170 (2001): 52.

8. Lock, *Court Rolls 1303-50*, 59.

couple of centuries earlier, the meaning was not as clear. The yeoman was still a serving man, but his class was unclear. In the ballads, the term probably refers to a peasant of free personal status.¹¹ Therefore, Robin Hood would not originally have been of noble birth, but a commoner. As Barrie Dobson and John Taylor wrote in 1976, “Robin Hood is presented as a yeoman hero for a yeoman audience.”¹² The stories of him were probably based on a class of people: criminals.

In fact, the name Robin Hood was used to address criminals. In 1331, a statute was passed by Parliament that stated all “roberdesmen” could be arrested, and a “roberdesman was any common thief.”¹³ This name resembles Robin Hood, although the name Robin Hood might likely be a derivative of robber. It is possible that this name and similar names were given to families of malefactors. This practice can be seen with the Robhood family discussed above. For example, on May 12, 1377 Peter Robhood broke into the lords’ pound and stole several animals. The court rolls state,

Peter Robhood [fined] 12d. because he broke [into] the lords’ pound, and took the beasts which had been seized by the lords’ bailiffs.¹⁴

There are many other examples throughout the court rolls of other people being referred to with the name Robhood after getting into legal trouble and paying lots of fines, thus suggesting that names such as Robhood may have been given to families that had members who would often misbehave. This may explain the name change from Fenner to Robhood in the court rolls examined here.

Despite Peter Robhood’s antics, the Robhood family were respected members of the community. Many people in Walsham Le Willows used them as pledges in court. Also, sometime after March 18, 1370 but before September 7, 1384, Nicholas Robhood became a chaplain; every reference to him in the court rolls after September 7, 1384 identifies him as chaplain.¹⁵ In order for Nicholas Robhood to become

a chaplain, he must have had a higher level of education than other people in the community, and he would have been a respected member of that same community.

This research is able to further the understanding of names, and more specifically, name changes, in medieval England. While it is known that surnames would regularly change, they were originally believed to have all occurred by choice. In certain instances, a family would attempt to adopt a new name, but the village could choose to veto this.¹⁶ Instead, the village could impose a permanent nickname that would become the family’s surname.¹⁷ The Robhood family is an instance of having a name forced onto them by the village. Some name changes were forced on some families as a form of punishment for misbehavior by one or more members of the family, a form of public moniker to bring shame to the family. While it was known that surnames could be changed forcefully, it was unknown that it could be done as a type of punishment.

The fictional character Robin Hood most likely received his name from the actual surname that appears in historical records. Many variations of the name Robin Hood, such as Robhood, appear in the English historical records, and they are almost always associated with people who commit crimes or misbehave. This is most likely how the mythical character in the stories got his name. Because Robin Hood and other variations of the name were used to describe outlaws and other miscreants, it is likely that the character in the original stories was given the name Robin Hood due to his actions as an outlaw.

The name Robin Hood has evolved over time. Today, scholars agree that Robin Hood was not a single person to be found in historical records. He was created as a character in a story to be told to others, a kind of campfire story. The name is formed from similar names that, at the time, were used to describe someone who was a miscreant. This does not mean that the idea of Robin Hood is not important, though. His story has created an entire cultural practice for people to explore. Just because

16. William F. Lanahan, “What’s in a Name? Family Surnames and Social Upheaval in Medieval England,” *Social Studies*, Vol. 11 No. 5, (Oct. 1, 1974), 219.

17. Lanahan, “What’s in a Name?” 219.

11. Almond and Pollard, “Yeomanry,” 53.

12. Almond and Pollard, “Yeomanry,” 52.

13. “Robin Hood.” *The Journal of Legal History* 11, no. 1 (April 30, 1990): 130–31.

14. Lock, *Court Rolls 1351-99*, 128.

15. Lock, *Court Rolls 1351-99*, 144.

he was never a real person does not mean that people cannot enjoy his tale and wish it was true. Robin Hood is no different from any other fictional character, and his message of helping the poor is important today. For this reason, he cannot be dismissed from history just because his history is grounded in myth. Rather he should be celebrated because his message still resonates strongly today. Now, more than ever, the idea of Robin Hood and helping those less fortunate is necessary.

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Sociodemographic Variables Associated to Anemia Among Agropastoral Mothers in Northern-Kenya

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Abstract

Maternal anemia is a global health issue. Reported risk factors include low socioeconomic status (SES), short inter-birth intervals (IBI), early time postpartum, and older age; however, general consensus is lacking. This study examined the associations of maternal anemia overall and two types of anemia: iron-deficiency anemia (IDA) and anemia of infection (AI), with SES, IBI, age, and time postpartum. The study used archival data from breastfeeding mothers during the 2006 drought in Northern-Kenya where IDA was prevalent. We expected anemia/IDA/AI to be associated with: low SES, shorter IBI, older age, and shorter time postpartum. These predictions were evaluated using *t*-tests and chi-square tests. Results were mixed. Mothers with any anemia were significantly younger and had earlier postpartum time than non-anemic mothers. SES was non-significant. Shorter IBI was associated with AI, but not with anemia/IDA. Risk factors of maternal anemia may be context-specific. During drought, risk of anemia by low SES may diminish, while age remains important.

Introduction

Anemia is a prevalent global public health issue that notably affects women of reproductive age (WHO, 2008). Anemia is defined as a low hemoglobin concentration in the blood, which can hinder oxygen delivery to tissues and therefore lead to serious health complications for pregnant and postpartum women. Anemia can be associated with poor cognitive and motor development, fatigue, low productivity, and increased rates of mortality for women and children (Stevens et al., 2013).

The different types of anemia include iron deficiency anemia (IDA), non-iron deficiency anemia (NIDA) and anemia of infection (AI). The most common type of anemia, IDA, is developed when the production of red blood cells is affected by insufficient iron intake or storage. NIDA is due to blood loss, red blood cell destruction, or micronutrient deficiencies other than iron. AI is due to infection or inflammation interfering with iron intake or storage (Fujita et al., 2019). In some situations, individuals may have anemia due to the combined effects of micronutrient/iron deficiency and infection/inflammation (Fujita et al., 2019).

High rates of maternal anemia have been reported among sedentary agropastoralists in Northern-Kenya. Our previous research reported that one in four mothers were anemic (Fujita et al., 2019; Corbitt, Paredes Ruvalcaba, & Fujita, 2019) and one in five mothers had IDA (Fujita et al., 2019). It is possible that anemia rates are heightened due to frequent droughts affecting livestock a major source of nutritious foods for agropastoralists.

Maternal anemia is generally associated with low socioeconomic status (SES; Ma et al., 2017; Balarajan et al., 2011). Mothers with low levels of education and low household wealth tend to be at a greater risk of anemia (Balarajan et al., 2011). This may be because mothers of lower SES also have a greater risk of poor nutritional status due to difficulties accessing iron-rich foods (Ghosh, 2009).

The literature is less consistent regarding the direction of association between maternal anemia and other maternal characteristics, such as age, inter-birth interval, and time postpartum. Regarding maternal age, previous research focusing on rural populations report older age (>40 years) as a

risk factor for anemia (Ma et al., 2017; Sadeghlan et al., 2013), although others report younger age as a greater risk (Gebremedhin & Enquselassie, 2011; Kaur, Deshmukh, & Garg, 2006), yet others report either extreme of the maternal age spectrum as risk groups (Scholl & Hediger, 1994). For IBI, a systematic review suggests that mothers with an IBI of under 5 months were at a higher risk for anemia (Conde-Agudelo, Rosas-Bermudez, & Kafury-Goeta, 2007), although a more recent study that adjusted for confounding variables suggests there is no association (Shachar & Lyell, 2012). In terms of time postpartum, previous research reports that mothers tend to have higher rates of anemia during the first days following delivery and recover after several weeks or months have passed (Bergmann et al., 2010). Other research conversely reports a higher prevalence of anemia during the late postpartum period (12 to 14 weeks) compared to early postpartum period (4 to 6 weeks) (Bodnar, Cogswell, & McDonald, 2005; Bodnar et al., 2001).

Across the literature, studies tend to focus on anemia as a general health concern and few studies evaluate the association of different types of anemia with socio-demographic variables. Distinguishing the different types of anemia, namely IDA and AI may clarify the inconsistencies in the literature in terms of the maternal characteristics that may be associated with maternal anemia.

Objective/Hypotheses

This study aimed to investigate the associations between maternal anemia and different types of anemia with age, SES, IBI, and time postpartum. We predicted that maternal anemia would be associated with: older age, low SES, shorter IBI, and earlier time postpartum.

Methods

This research used cross-sectional archival data from 237 breastfeeding mothers, originally collected during the 2006 Horn-of-Africa drought in Northern-Kenya. The original study was based on a stratified random sample of 241 seemingly healthy breastfeeding women (Fujita, 2008). The inclusion criteria for the present study were being 18 years of age or older and having complete data for the variables of interest: anemia status, iron status, sub-

clinical infection/inflammation status, SES, IBI, maternal age, and time postpartum.

Variables

Anemia was defined as having low levels of hemoglobin (<12 g/dL). IDA was defined as anemia with iron deficiency (sTfR>5 mg/L DBS). AI was defined as anemia with subclinical infection/inflammation (CRP>5 mg/L). Low SES was a self-report of poverty and below-median land size and livestock owned by the household. IBI was defined as the number of months between births of previous and current infants. Data on maternal age and time postpartum were available from interviews.

Statistical Methods

This study utilized *t*-tests and chi-square tests using Stata version 13. The alpha-level was set at .05.

Results

The result of the *t*-test indicated that the anemic group of mothers was younger on average (*Mean* = 25.72, *SD* = .77; Table 1) compared to mothers with no anemia (*M* = 28.68, *SD* = .52; *p* = .002; Figure 1). Likewise, the groups of mothers with IDA (*M* = 25.53, *SD* = .83) and AI (*M* = 24.10, *SD* = 1.30) were younger compared to mothers with no IDA (*M* = 28.52, *SD* = .50; *p* = 0.006) or no AI (*M* = 28.19, *SD* = .46; *p* = 0.026), respectively (Figure 2).

TABLE 1. Maternal sociodemographic characteristics by maternal anemia status.

Mean ± SD or %	Overall (n = 237)	Anemia (n = 58)	No Anemia (n = 179)	T-Test P-value ¹
Age (years)	28.0 ± 6.8	25.7 ± 5.9	28.7 ± 7.0	0.002
Time Postpartum (days)	243 ± 134	207 ± 131	254 ± 133	0.010
Inter-Birth Interval (months) ²	35.4 ± 14.6	36.4 ± 16.3	34.7 ± 16.3	0.680
Low SES	25%	29.3%	23.5%	0.371 ¹

¹Chi-Square P-value. ²Smaller sample sizes (excluding primipara): Overall n = 64, Anemia n = 25, No Anemia n = 39

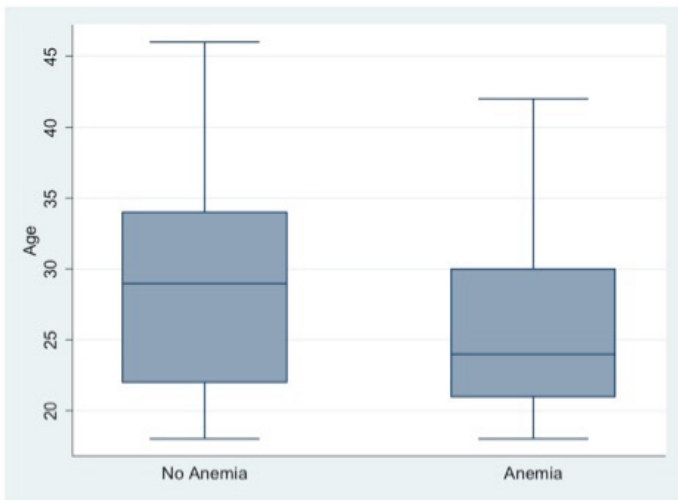


FIGURE 1. Anemic mothers ($n = 58$) were younger than non-anemic mothers ($n = 179$, $p < 0.004$).

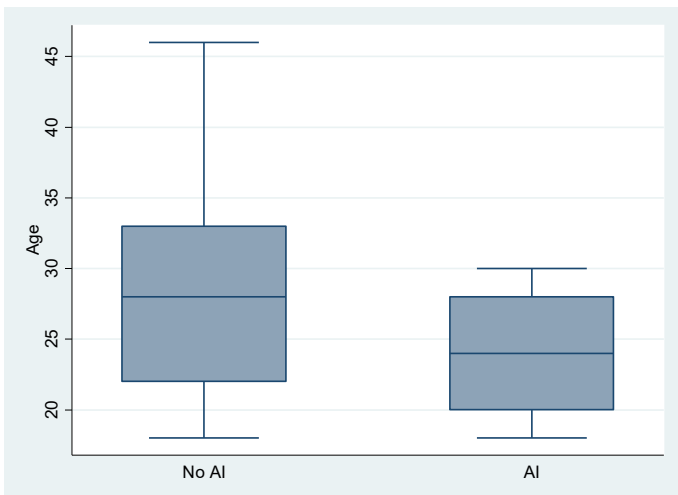
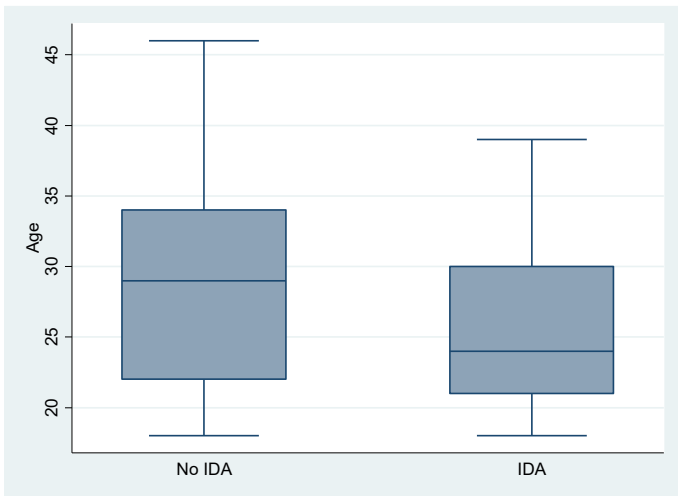


FIGURE 2. Mothers with iron deficiency anemia (IDA; $n = 40$) were younger than mothers with no IDA ($n = 194$; 26 vs. 29 years, $p = 0.01$). Mothers with anemia of infection (AI; $n = 11$) were younger than no AI ($n = 224$; 24 vs. 28 years, $p = 0.05$).

Anemic mothers had earlier postpartum time ($M = 207$, $SD = 131$) than mothers with no anemia ($M = 254$, $SD = 133$; $p = 0.010$; Figure 3). Mothers with IDA also

had earlier postpartum time ($M = 209$, $SD = 135$) than mothers with no IDA ($M = 250$, $SD = 133$; $p = 0.037$). Mothers with AI had earlier postpartum time ($M = 176$, $SD = 95$) than mothers with no AI ($M = 245$, $SD = 135$; $p = 0.047$).

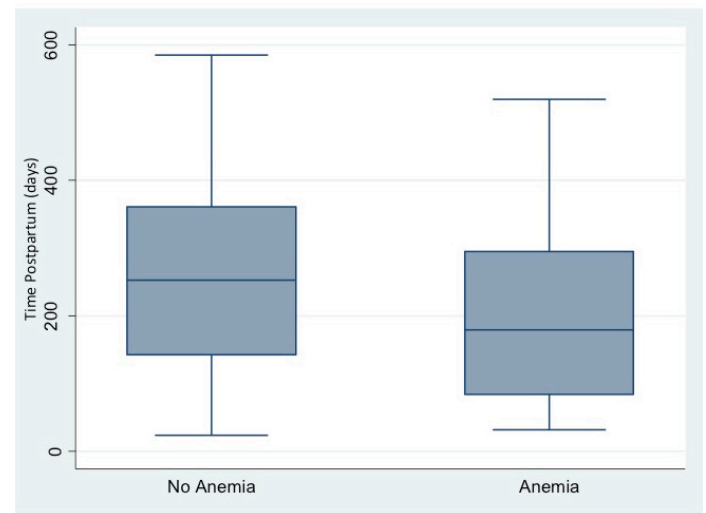


FIGURE 3. Anemic mothers ($n = 58$) had earlier time postpartum than non-anemic mothers ($n = 179$, $p = 0.02$). Also, mothers with iron deficiency anemia (IDA; $n = 40$) had marginally earlier time postpartum than non-IDA mothers ($n = 194$, $p = 0.07$).

There was a significant relationship between IBI and AI, such that shorter IBI was associated with AI ($M = 16$, $SD = 11$) than in mothers with no AI ($M = 36$, $SD = 14$). IBI was not significantly associated with anemia or IDA. The results from the chi-square test showed no association between low SES and anemia/IDA/AI.

Discussion

This study assessed maternal anemia and types of anemia in relation to socio-demographic variables including: maternal age, SES, time postpartum, and IBI. It was hypothesized that maternal anemia and the different types of anemia would be associated with older age, low SES, short IBI, and an earlier time postpartum. Our results were partially as expected. Consistent with our expectation, earlier time postpartum was associated with maternal anemia, IDA, and AI. Shorter IBI was only positively associated with AI, but not for anemia or IDA. Contrary to our expectations, mothers with anemia, IDA, and AI were significantly younger. Unexpectedly, SES was not associated with anemia, IDA, or AI.

Our results indicating the association between younger maternal age with anemia, IDA, and AI side with the literature that reports younger age as a risk

factor for maternal anemia (Gebremedhin & Enquselassie 2011; Kaur, Deshmukh, & Garg, 2006). The association between younger mothers and anemia and IDA may be due to an elevated need of nutrient requirements in younger women who may be still allocating nutrients towards their growth and development, resulting in low iron storage and a higher risk for anemia and IDA.

Contrary to our expectations, this study found no significant associations between low SES and anemia/IDA/AI. Our findings are in opposition to the literature that reports an association between low SES and anemia (Ma et al., 2017; Balarajan et al., 2011; Ghosh, 2009). It is unclear why we did not observe a significant relationship between SES and anemia. One possibility is that SES-based group differences that ordinarily exist diminished in the context of prolonged drought. Although droughts would affect all mothers in northern Kenya, the drought could minimize the nutrition/health advantage of wealthier mothers if, for example, poorer mothers were preferentially receiving drought-relief food distribution (Paredes Ruvalcaba, Bignall, & Fujita, 2020).

The observed results regarding the association between earlier time postpartum and anemia/IDA/AI sides with the literature that suggests that early time postpartum is an important factor in relation to maternal anemia (Bodnar, Cogswell, & McDonald, 2005). In terms of IBI, our study found an association between shorter IBI and maternal AI, but no association between IBI with anemia or IDA. The association between IBI and AI are in line with previous research that has reported that shorter IBI increases the risk for maternal anemia (Conde-Agudelo, Rosas-Bermudez, & Kafury-Goeta, 2007). Previous studies that account for confounding variables has reported no association between IBI and maternal anemia (Shachar & Lyell, 2012). That this association is significant only for AI but not for IDA or anemia overall in the present study suggests the possibility that shorter IBI increases the risk of anemia due specifically to infection/inflammation. Future studies should investigate this possibility by evaluating maternal anemia types and IBI using a greater sample size while accounting for other possible confounding variables.

Conclusion

Maternal anemia is a prevalent health issue globally, but consensus is lacking as to what sociocultural or demographic factors may increase or decrease anemia risk. Analyzing the data from drought-affected Northern-Kenya while distinguishing different types of anemia in light of previously published studies from other parts of the world, suggests that the associations between socio-demographic variables and maternal anemia may be context-specific. During a severe drought, differences by SES may diminish, while maternal age remains associated with anemia. Future research should more carefully evaluate the reported associations, including the possible role of confounding variables.

Acknowledgements

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Lament for Aleppo

Sameed Ahmed Khan | Lyman Briggs College

Ya Halab,
Your silence sang its clarion call,
Past the mortars and their screaming fall,
Past the guns in the shouting streets,
From the half-million dead heartbeats.
And the debris stands as witness there,
to the corpses unnamed and undeclared.
Ya Ash-Shahbaa (*The White One*),
your white face now masked in red,
your body scarred by their tank treads,
your laughing streets and towering domes
now scattered rubble and deserted homes.
Your floating parapets and balconies,
ground to dust beneath their marching feet.
Your walls, sentry against Kitquba and Tamerlane,
now hear again, the gray refrain,
of cacophony in bullets and shells:
the litany of knives delicately held,
to draw the deed—to end a painful hope,
that your flaming cries would draw to close.
Pray,
Pray for Aleppo,
whose children cry beneath the ground,
whose final requiem rings and resounds
crimson tones of death and dreams denied,
for here its burning freedom came alight—
here, its desperate martyrs lived and died.
Pray for Aleppo,
whose elegies have borne and bled,
the silent sighs of the watching dead.

MSU Year of Global Africa

Camellia Landman | Department of English

The 2018-2019 theme for the Year of Arts and Culture was Global Africa. With Africa's growing global presence in the twenty first century, and Michigan State University's long history working with regions of the continent, it is no surprise that this thematic year explores Africa's past and future. Since helping to establish Nigeria's first indigenous university, MSU has maintained a strong connection with the continent. From cultural programs and initiatives to study abroad programs, MSU's relationships with Africa continue to grow.

To honor Africa and Michigan State's connection with the continent, cultural events and thought-provoking discussions were held across campus. The MSU Marching Band performed a "Celebration of Africa" routine at the MSU vs. Maryland football game. The show was designed by Ben Ayettey, artistic director at the Ghana Dance Ensemble and fellow at the Institute of African Studies and the University of Ghana. Ayettey collaborated with the band and even led the drum line. The MSU Marching Band was joined by 250 singers from the MSU choirs, as well as members of the color guard and the cheerleading team. Yacouba Sissoka, a world-renowned kora player from Mali joined in the performance. The "Taste of Africa" event offered students a chance to learn African styles of cooking and dance. The Michigan State University Library held an exhibit, "Nsukka to Now: The History of African Studies at MSU," to honor the Year of Global Africa. The exhibit showcased Michigan State's connection with Africa, focusing on partnership, innovation, and activism.

The Rwandan Genocide Commemoration offered a chance to look back and remember the pain of not only the Rwandan genocide, but the Armenian genocide and the Holocaust as well. The event had

themes of remembrance and encouraged its attendees to look toward the past to move into the future. The Ethiopia Forum explored challenges and opportunities Ethiopia would face as they move toward a constitutional democracy, as well as offering a place for healthy debate and discussion on contemporary politics.

The Year of Global Africa follows a long line of thematic years run by the MSU Cultural Engagement Council (CEC). The council is made up of college deans and the directors of the MSU Museum, Broad Art Museum, The Wharton Center, and Abrams Planetarium. This diverse group of people seeks to offer cultural understanding not only to students, but also to the community. Chaired by Kurt Dewhurst, director of UOE's Arts and Cultural Initiatives, the CEC works to provide opportunities to people to learn about and engage in cultures they might be otherwise unfamiliar with. Along with Dewhurst and the CEC, the Year of Global Africa team included Jamie Monson (Director, African Studies Center MSU), Leo Zulu (Associate Professor, Department of Geography MSU), Stephen Esquith (Dean, RCAH MSU), and Lisa Fruge (Project Event Coordinator, African Studies Center MSU).

In a political climate that supports separation, Michigan State University's thematic years promote connection and togetherness. The thematic years work to bring the student body together. They provide a priceless opportunity to students, allowing them to be immersed in and exposed to cultures oceans away from the comfort of campus. The MSU Arts and Culture's Year of Global Africa is one of many events on the Michigan State University campus that works towards inclusion and global thinking.

Fossilized Turtles: Missing Shells, Missing Ancestors, Many Techniques

Alena Bowman | Lyman Briggs College

Abstract

Turtles (Order Testudines) are a diverse group of reptiles that have been around relatively unchanged since the Mesozoic Era. There are many fossils of turtles from throughout Earth's history; those remains have been used in a variety of ways to study the evolution and paleoecology of these reptiles. Soft-shelled turtles, in particular, have a unique and well-researched evolutionary history involving secondary trait loss. Differing research techniques and processes between archaeological and genetic researchers have fostered disagreement surrounding the origin of Testudines. These debates may affect phylogenetic construction. Research into turtle evolution has the potential to impact studies of turtles' ability to adapt to today's quickly changing world.

Introduction

Order Testudines has many colloquial names in English, the most popular of which is "turtle." Today, there are 356 known species of turtle, but fossils of these reptiles' ancestors have been found dating back to the early periods of the Mesozoic era. How do we know that the turtles of the Early Cretaceous period are related to turtles in modern times? Recently, techniques have been developed to analyze mutation rates in turtles' DNA to predict when species separated from each other and to assist in determining turtle ancestry. The fossil record has been providing interesting insight into turtle phylogeny for much longer. However, the accuracy of evolutionary research is threatened as turtles are increasingly endangered by climate change, affecting their evolution and/or extinction rates. This review evaluates the current state of research into turtle evolutionary history. Future researchers will need to analyze the changing rates of turtle evolution and what this would mean for the evolution and conservation of all species.

Studying Turtle Evolution

Reptile body fossils are common because of the presence of a bony skeleton, which preserves well. Despite fossils of marine reptiles being relatively common even among vertebrates – e.g. about 25% of the total known vertebrate species are in the Phosphates of Morocco (Bardet et al., 2013) – fossils of early turtles are rare, with intact shells even less common (Benson et al., 2016). Ancient shells and bones tend to be crushed by surrounding sediment. Still, turtle fossils make more suitable subjects for fossil-based evolution research than some other vertebrates because ancient turtles were morphologically very similar to modern-day turtles. There is a stronger relationship between *Odontochelys* and modern turtles than with other modern species and their ancient ancestors, making it comparatively easy to look for intermediates and create a timeline of pantestudine evolution.

Even within the fossil record field, there are different ways of creating relationships between extinct and extant species. Benson et al. (2016) studied shell geometry of living turtle species in three dimensions in order to create an algorithm that distinguished between terrestrial and non-terrestrial turtles. That information was used to predict the environments of ancestral turtles, which were both terrestrial and aquatic habitats (Benson et al., 2016). This indicated ecological plasticity, still present in modern turtles. The diverse niches filled even by early turtles could indicate that turtles were evolving before the Late Triassic (Benson et al., 2016).

Turtles further diversified later in the Mesozoic Era. Bardet et al. (2013) studied the skull morphology of a recently unearthed turtle fossil, comparing it to beaked whales and syngnathiform fishes. Those comparisons led to the conclusion that the turtle *Ocepechelon bouyai* (-66 Ma) was aquatic and its bony snout allowed it to hunt like a crocodile, breathing with its nose above the water's surface. This respiration technique was like that of today's soft-shelled

and pig-nosed turtles, indicating a possible ancestral relationship, but *O. bouyai* was unique in its bony structure, as all nose-tube structures today are made of soft tissue (Bardet et al., 2013).

One problem with the fossil record is that it has gaps that prohibit a cohesive timeline of turtle evolution. Schoch and Sues (2015) examined a new fossil, which they named *Pappochelys*, that helped fill a gap between *Odontochelys* (220 million years old) and *Eunotosaurus* (Permian period, 260 million years old). The discovery of this stem-turtle assists with tracing the origin of the turtle shell and the loss of their teeth. *Pappochelys* had teeth, as did *Odontochelys*, while extant and fossilized turtles discovered since do not. The cross-section of *Pappochelys*' ribs resembled that of *Eunotosaurus* and *Odontochelys*, placing it as an intermediate form between them. This fossil hadn't yet developed a fully formed plastron like *Odontochelys*, a feature that remains in today's testudines, but it did have the precursor, "gastralia," structures that were present in *Eunotosaurus*. This study thoroughly demonstrates how the fossil record can be used to construct an organism's evolution. Looking at *Eunotosaurus* (~260 Ma), *Pappochelys* (~240 Ma), *Odontochelys* (~220 Ma), and *Proganochelys* (215 Ma) and comparing the morphological aspects of each fossilized taxa, the researchers constructed a timeline of when each feature evolved (Schoch and Sues 2015). With each change in morphology, the early turtles became closer to the turtles we recognize today.

Additional study of the microanatomy of *Pappochelys*' vertebrae revealed that the turtles had burrowing abilities, most likely with a terrestrial or amphibious lifestyle rather than an aquatic one (Schoch et al. 2019). The earlier *Eunotosaurus* was a terrestrial reptile, but *Odontochelys* has controversially been claimed to have had an aquatic lifestyle. Extant turtles exhibit preferences for aquatic, semi-aquatic, and terrestrial habitats and it is difficult to predict a turtle's preference based on their morphology and microanatomy. Schoch et al. (2019) warn that "[m]orphology and microanatomy do not always correlate directly to habitat preference," especially in animals that have an evolutionary history of switching their preference from one habitat to another. The researchers included many figures illustrating the bone formation of each taxon in their article, convincingly supporting the intermediate morphol-

ogy of *Pappochelys* between *Eunotosaurus* and *Odontochelys*.

Lichtig et al. (2017) addressed an aspect of the fossil record that has been overlooked by other studies: fossilized tracks. These tracks are "the oldest fossil evidence of turtles" and date back to before the Mesozoic Era (Lichtig et al., 2017). Track fossils are often older than body fossils; the oldest turtle tracks are 247–249 million years old while the oldest body fossils from *Odontochelys* are 233–237 million years old (Lichtig et al., 2017). Research about how turtles moved is instrumental to increasing understanding about ancient turtle lineages; it provides more information about when and where organisms lived, without requiring the rare discovery of a skeleton.

Footprints and bones aren't the only remnants of ancient turtles. Chemical remains of pigmented skin have been used to discuss the convergent evolution of pigment in marine animals and its possible benefits for extinct and extant organisms (Lindgren et al., 2014). In particular, skin pigment affects the ability of these groups to survive in cold environments, which has implications for paleoecology discussions. Research on the complex process of evolution is not limited to fossils alone. Terrestrial and aquatic turtles also have different levels of diversity because of different genetic modes of evolution (Stayton et al., 2018). The genotype of an organism is not visible in fossils but is important for evolution, as mutations in the genotype create diversity. Therefore, studying the fossil record of an organism alone has limitations.

Soft-shelled Turtles

Soft-shelled turtles have an intriguing evolutionary history. Their highly aquatic lifestyle and lack of keratinous scutes set them apart from the rest of the turtles. The loss of hard shells is secondary; soft-shelled turtles evolved hard shells but reverted back to the morphology of a bony shell covered with leathery skin. Their soft shell assists them with respiration in their aquatic habitat (Escalona et al., 2017) and decreases the necessity for hard minerals (Scheyer et al., 2007).

Fossils of crown (ancestral) soft-shell turtles date back to the Early Cretaceous period; trionychid turtles have remained relatively unchanged in the

last 120 million years and have spread across four continents (Scheyer et al., 2007). Scheyer et al. (2007) and Brinkman et al. (2017) both studied the evolution of soft-shelled turtles since their beginning, with Scheyer et al. positing that the turtles' evolutionary success is due to their unique, plywood-like shell structure. Brinkman et al. researched the stem lineage of soft-shelled turtles by looking at recently discovered fossils and comparing their ossification pattern in order to propose a new phylogeny. The discovery of Brinkman et al.'s fossil in southeastern China from the Early Cretaceous adds support to Scheyer et al.'s belief in soft-shelled turtles' evolutionary success as it adds range to both the distribution and the diversity of trionychids.

Escalona et al. (2017) did not utilize just the fossil record to create the phylogeny of soft-shelled turtles, but also used genetic analysis. Genetic analysis allowed them to trace the evolution of specific traits. However, accurate genetic analysis typically depends on assuming an average mutation rate. One concern is that modern-day climate change may affect mutation rates and thus potentially affect the accuracy of genetic analysis.

Turtle Locomotion

Given that stem-turtles were, and modern-day turtles are, tetrapods, there is a surprising amount of evolutionary history involved in the study of turtle locomotion. This is likely due to their tendency to transfer between aquatic and terrestrial ecosystems, which complicates their locomotive evolution. Young et al. (2017) addressed this issue by looking at the evolution of flippers in vertebrates and the implications this has for aquatic reinvasions, which have been observed in turtles with their fluid habitat preferences. Patterns of fossilized tracks can be used to determine how ancient turtles moved and whether they were primarily aquatic or terrestrial (Lichtig et al., 2017). The sediment in which the tracks are found can also be used to study paleoecology and habitat preference (Reolid et al., 2018).

Using complete skeletons of Jurassic-era marine turtles, Szczygielski et al. (2018) analyzed mandible morphology and bone weathering (like Scheyer et al., 2015) instead of limbs to determine their aquatic locomotion, as forelimb data was lacking. Developmental differences were found between the

phalangeal development in herbivorous *Carettochelys* and carnivorous trionychids, both of which are aquatic turtles, indicating that aquatic vs. terrestrial habitat distinction is not the only determining factor in the evolution of turtle locomotion (Delfino et al., 2010).

Looking at the Paleoecology

In addition to looking at the structures of fossils themselves, paleontologists look at the environment surrounding the fossilized organisms. Dating the elements found surrounding a fossil can help determine the age of a layer of sediment, creating a calibration for the fossil record timeline. Sediment type and indications of plant life are also used to determine if a turtle was aquatic or terrestrial. For example, Difley et al. (2002) analyzed sediment stratification and found turtle and fish skeletal fragments among mudstone and shale beds, indicating that this area was aquatic, so the turtles were likely aquatic or semi-aquatic. This is not always accurate because turtles are flexible in their habitat preferences and even terrestrial turtles end up near water occasionally. An added challenge to accurate determination is that only skeletal fragments were found, with no complete skeletons, prohibiting species-level analysis. Techniques like those of Benson et al. (2016) could be instrumental in situations where it is unclear what environment a turtle inhabited, although their shell geometry method was more accurate in differentiating between terrestrial and non-terrestrial than the more amorphous categories of aquatic and semi-aquatic.

Fossilized turtle shells can also be used to study paleoecology. Scheyer et al. (2015) devised a method to study even tiny fragments of the shells of solemydids (a line of "stem-turtles") to determine their preferred habitats. If many turtles were terrestrial, the area was not likely covered in water. Furthermore, they looked at the increased weathering of these turtles' fossils compared to the weathering of other preserved organisms in the area and found that the *Solemys* turtles weren't local. The typical technique of looking only at the surrounding area for ideas about an organism's environment may have indicated that the ancient turtles lived in the area where they were found, with the other species found there, but that may not be the case. The methods of Scheyer et al. would minimize the risk of making inaccurate assumptions.

An additional, unique method for evaluating the paleoenvironment was discussed in Matson and Fox (2008) who looked at oxygen isotopes in turtle bones. Similar studies had been conducted previously, providing methods and data to compare new findings. Matson and Fox concluded that turtle isotopes could be compared to other cold-blooded animals, like crocodylians, that lived around the same time and area in order to estimate paleotemperatures from oxygen isotopes. However, they note that their study should not be generalized yet; it may only apply to the specific environment that they looked at.

Debate around Testudines' Origins

It is generally agreed that the earliest turtles existed during the Mesozoic Era, likely since the Early Cretaceous period, although Lichtig et al. (2017) reminded the field that turtle tracks have been found dating back to the Cenozoic Era. Joyce and Gauthier (2003) argue that the earliest turtles and the common ancestors of turtles are different concepts. Lichtig et al. (2017) agree that *Pappochelys* (Schoch and Sues 2015) may not be considered a turtle. Schoch et al. (2019) are careful to note the contrast between *Pappochelys* and “turtles.” It is also possible that *Odontochelys* is the oldest, undisputed turtle body fossil, but isn't the ancestral turtle. By the Late Triassic, there were already four family-level groups, indicating evolution from a much older, original turtle (Lichtig et al., 2017; Joyce, 2017). Scheyer et al. (2014) propose that solemydid turtles are stem-testudines but aren't from either of the two major branches of crown turtles, which may or may not have extant descendants. Regardless, research into the origin of the turtle body plan has already revealed intriguing insight into the formation of the shell.

The phylogeny of turtles continues to develop. New techniques offer novel insights about turtle evolution. Lee's (2013) incorporation of molecular analysis has created phylogenies that have the potential to contradict observation of fossil record morphology. This, however, does not have an impact on the lives of today's turtles. The only level of classification that matters in nature is species, as that affects social interactions and reproduction.

Discussion

Researchers should continue to search for turtle fossils, both body and tracks, to fill in the gaps in the fossil record. Increased collaboration between researchers using fossil and genetic techniques may also help yield more agreement about turtle phylogeny. However, it is also likely to lead to more debate as the consensus evolves with new technology. More fossils and data collection will be necessary. Lindgren et al. (2014)'s publication about the ability of pigmentation to contribute to thermoregulation in different animal groups has the potential to impact today's climate discussions and turtles' ability to adapt to today's quickly changing world. Future research may investigate how pigmented organisms that typically inhabit cold environments are affected by increasing global temperatures; the expectation would be that as temperatures increase, organisms would have a lower threshold for pigmentation requirements.

Acknowledgments

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Tomorrow

Dev Dayal | Lyman Briggs College

Today I woke up.

Your arms were wrapped around me,
Tight with a yearning embrace.
The sky was bright blue,
The clouds were animated,
The wind bellowed and
Carried with it
Echoes of happiness.
Sounds of our future,
Together.

Today I woke up.

To sheets left in a frenzy of twists,
you left in a hurry.
The sky was an omnipotent grey,
The clouds,
embellished with ridges
Gave way
To dense hissing winds.

Overcome by a feeling so unfamiliar,
Like the depths of a frozen place,
Darkness
Begged to consume the light.

Today I woke up.

As I wiped the fog away,
We locked eyes in the mirror,
As you dressed,
You boasted an irreplaceable beauty
Of character
And self.
The sky was blue,
There were no clouds,
The wind boasted an undertone
of embellished nonexistence.

Today I woke up.

Empty,
I ached
For your gentle touch.
At that moment,
I realized the love I had for you.
I went to text you

Those three magical words.

I looked at the news.

Today I woke up.
You didn't.

Today I went to school.
You didn't.

Today I went to work.
You didn't.

Engulfed by winds carrying
Shrieking echoes
Of mourning
And pain.
Our future was taken,
Stripped,
Frozen in time.

Today I woke up.

Hoping it was a dream.

In this nightmare,
Today I woke up,
But
Tomorrow,
I might not.

We often forget that reality is a lucid dream,
We are in control,
We must flip the script.

If we all die in our nightmares,
Reaching for our dreams.
The darkness envelopes the light,
And
We will be alone in the night.

We must cope,
Cherish the day,
Stop the mass bloodshed,
The violence,
The mourning.
Dreams shouldn't end like this.

A *Plasmodium falciparum* Aldolase ELISA Assay to Measure Total Parasite Load in Patients with Malaria

Racheal Nassimbwa | Biomedical Laboratory Diagnostics Program

Abstract

Uncomplicated malaria is a common condition among children in sub-Saharan Africa. The WHO estimates Africa faced more than 268,000,000 cases in 2018 alone.¹ With appropriate treatment, most of these children will recover. However, a portion of these cases progress to potentially fatal cerebral malaria despite appropriate treatment. Identifying in the early stages of the disease those children with a high risk of developing cerebral malaria would allow for the timely and appropriate use of available resources and could decrease disease progression and severity. The number of parasites in the peripheral bloodstream is measured with a finger prick and a blood smear. This metric, peripheral parasitemia, is not a good predictor of progression to cerebral malaria. The inability of peripheral parasitemia to track disease progression is due to the lack of this measure to account for parasites that are sequestered in deep tissues. The total body parasite load is defined as the parasites seen in the periphery plus those parasites which are sequestered in the deep tissues, and has been shown to be a better predictor of progression to cerebral malaria. Although there are currently measures to determine total body parasite load, they have limitations and additional tests are needed. The objective of this project was to develop an assay to determine plasma concentrations of a malaria protein, *Plasmodium falciparum aldolase*, which might serve to better measure the total body parasite load in malaria patients.

Introduction

Malaria is a deadly infectious disease with significant global impact among children under 5 years of age especially in sub-Saharan Africa. Despite various interventions to reduce the incidence and mortality rates of malaria in Africa, the World Health Organization (WHO) in 2017 attributed 435,000 deaths to malaria.¹ There are many children infected

with *Plasmodium falciparum* without clinical symptoms and among those with symptoms, only a small percentage progress to cerebral malaria, the deadliest form of severe malaria. Cerebral malaria is defined as a Blantyre coma score of ≤ 2 , peripheral parasitemia and no other discernible cause of coma.² Progression of uncomplicated malaria to cerebral malaria could possibly be due to a variety of causes, including delayed diagnosis or inadequate treatment; however, in most patients no definitive cause for the progression is identified. If medical practitioners could identify children that are more likely to progress to cerebral malaria, they could immediately triage these vulnerable patients to receive more intense therapy. In regions of low resources, early and accurate triage is vital to maximizing the resources that are available and could result in increased survival in this subset of patients. The measure of total parasite body load by ELISA has been shown to be an accurate predictor of progression to cerebral malaria.² There are currently two parasite-specific proteins that have been used to measure the total body parasite load, however, neither are ideal. One of the proteins, *Plasmodium falciparum* histidine rich protein 2 (pHRP-2) has a relatively long half-life of 4.8 days. This long half-life leads to residual circulating protein even after an acute infection has been cleared. The other protein, *Plasmodium falciparum* lactate dehydrogenase (pLDH) has a very short half-life of 1.8 days which may result in the inability to detect the most recent round of parasite infection.³ The limitations of both of these proteins has led us to investigate the possibility of using a third parasite-produced protein, *Plasmodium falciparum* aldolase (pAld) for the same purpose. pAld is another protein released from parasite-infected red blood cells during the parasite life cycle. pAld half-life is intermediate between pHRP2 and pLDH at 3.2 days.³ The objective of this project is to develop a quantitative assay measuring pAld. This might enable better prognosis of malaria and reduce cases that progress to cerebral malaria in children. The

long-term goal of this project is to develop a multiplex assay that can detect all three plasmodium proteins; pHRP2, pLDH, and pAld using one plasma sample to simultaneously evaluate the prognostic ability of the three assays in parallel.

Methods

To develop the most sensitive pAld Enzyme Linked Immunoassay (ELISA), we evaluated two commercially available coating antibodies against pAld and two commercially available detection antibodies specific for pAld. The two Coating antibodies (CAb) were CAb 1 – MyBioSource Cat # 563517 and CAb 2 – Abnova Cat # PAB 29677. The two Detecting Antibodies (DAb) were DAb 1 – Abnova Cat # 29676 and DAb 2 – MyBioSource Cat # 563516. The two coating antibodies and the two detecting antibodies were each tried at three dilutions in a checkerboard protocol to determine the combination of antibodies that would provide the most sensitive assay. As recombinant pAld was not available, tissue culture supernatant of cultured *P. falciparum* parasites was used as a standard to evaluate sensitivity.

Results

Representative data from a checkerboard ELISA experiment is shown in Figure 1. The results show a clear superiority of DAb 1 over DAb 2. The differences in CAb was less profound and CAb 1 was chosen for further development of the assay. Further optimization of the assay with these two antibodies resulted in final dilutions of 0.3µg/ml for the DAb and 1.0µg/ml for the CAb. A finalized Standard Operating Procedure (SOP) is included as online supplementary material.

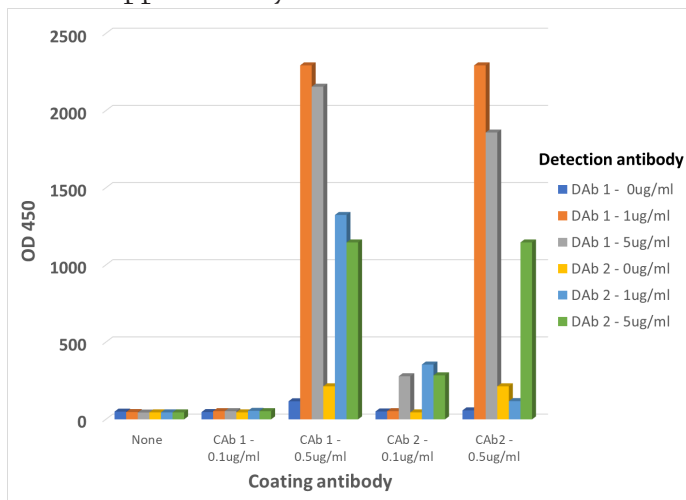


FIGURE 1. Reaction between the coating antibody and detecting antibody at different concentrations.

Discussion

Malaria still remains a risk and public health threat to many lives especially children in sub-Saharan Africa. United Nations International Children’s Emergency Fund (UNICEF) estimated a daily toll of about 730 malaria deaths among children under 5 in 2017.⁴ Prompt and accurate diagnosis of malaria are key in effective management of the disease; however, there are still gaps in efficiently predicting and monitoring disease progression. Only a small proportion of infections with *P. falciparum* progress to severe disease. A challenge in malaria control has been the determination of which of these infections are most likely to progress to life-threatening disease. With the development of the pAld assay, we hope to be able to more accurately determine total body parasite load which serves as an accurate predictor of disease progression. The next step will be to use the optimized pAld assay on a group of clinical samples – some of which progressed to severe disease and some which did not – to determine if the assay is able to predict disease progression. A long-term goal would be an assay that would not only multiplex the three *Plasmodium* proteins, pHRP-2, pLDH and pAld, but could also be adapted to a point of care assay. The information obtained from such an assay would provide insight early in the disease process as to the possibility of the patient progressing to severe disease. This would allow a medical practitioner to rapidly triage the patient to the most efficient therapy and reduce the chances of severe disease. In low-resource settings, such rapid triage would allow for appropriate use of the limited resources available.

Acknowledgments

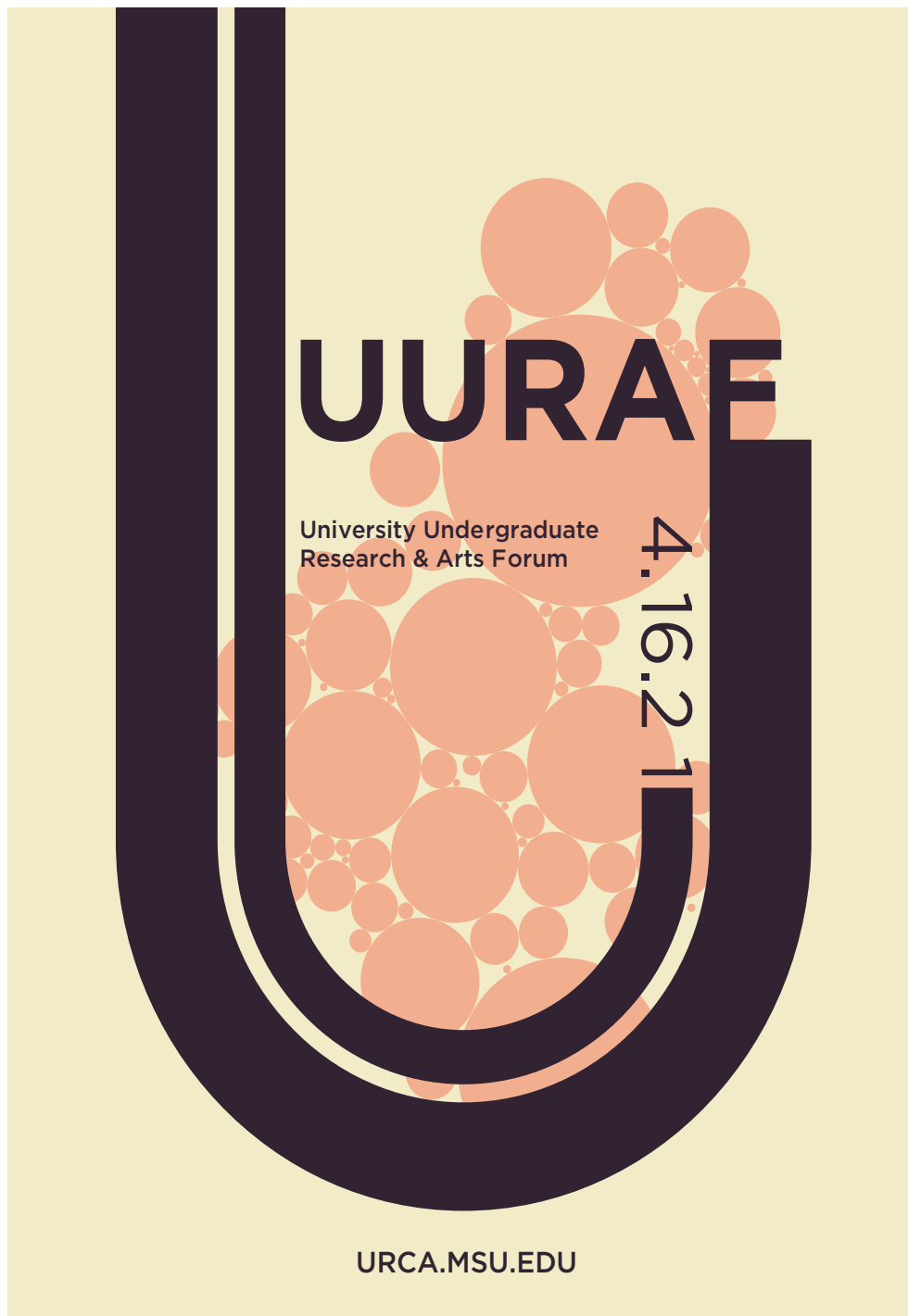
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Highlights of Undergraduate Research

- Anderson, M. "After Your Dreams," Fresh Inc, 3-16 June 2019.
- Blythe, J. "Germany's Post Reunification Mega Events: Planners Intentions verses Residents Perceptions," 10-14 April 2018.
- Declerck, C. "Comparing FE and Camped Parameter Models to Predict the Effects of Myocardial Infraction," Biomedical Engineering Society Annual Meeting, 17-20 October 2018.
- Felster, R. "Scalar Implicatures: Formal and Experimental Exploration," Italy Workshop, 11-13 July 2018.
- Foster, K. "Mindful of Mistakes: Parsing the Polylactic Nature of Mindfulness in Relation to Error Monitoring," Association for Psychological Science Conference, 24-27 May 2018.
- Greesson, D. "Learnability in Romance: How Indirect Input Helps Children Acquire the Contrast Between Null and Overt Subjects," Hispanic Linguistics Symposium, 25-27 October 2018.
- Hughes, K. "Improving Accessibility within Museums Through Multiple Literacies," National Conference on Undergraduate Research (NCUR), 4-8 April 2018.
- Jansen, G. "Effect of Temperature on Human J1-8 Antibody Activity on Biofunctionalized Diamond Sensor Surfaces," International Conference on Diamond and Carbon Materials, 8-12 September 2019.
- Jones, R., Cannon, T. "Workshop for Rapid Diagnosis of Tuberculosis/Rapid Tuberculosis Detection Using Magnetic Nanoparticles," Rapid Tuberculosis Detection Using Magnetic Nanoparticles, 22-23 May 2019.
- Kindig, G. "A Cross-cultural Approach to Narrative Experiences of Music," APCAM/Pyschonomics, 15-17 November 2018.
- Komosinski, B. "Acting as Neither Individual nor Professional: Physicians Constructive Ambivalence in Adopting Complex Technologies," American Sociological Association 2018 Annual Meeting, 11-14 August 2018.
- Manzo, A. "How to Authentically Engage Emergent Bilinguals Through the Creation of Multi-modal Digital Resources," NABE-Biliteracy as a Global Imperative, 7-9 March 2019.
- McClure, S. "Boron-Doped Diamonds Carbon Paste Electrodes", 2018 Army Science and Tech Symposium & Showcase, 21-23 August 2018.
- Merlino, S. "A Bear, A Mammoth, and a Sheep Walk into A Bar: Museum Twitter Mascots in Small to Mid-sized Organizations," Museum Computer Network 2018 Conference: Humanizing the Digital, 13-16 November 2018.
- Muethel, A. "Searching for Shocks in Novae from Hard X-ray Emission," Compact White Dwarf Binaries, 15-21 September 2019.
- Murrin, M. "Self-disclosure Moderates Associations Between Parentification and Adjustment and Relationship Quality Among Typically Developing Siblings of Individuals with Autism Spectrum Disorder," Society for Personality and Social Psychology Annual Convention, 7-9 February 2019.
- Nitzkin, J. "Second Formant Transitions Differentiate Children with Persistent Stutter from Fluent Peers," International Conference on Stuttering 14-16 July 2018.
- Peng, L. "Mindful of Mistakes: Parsing the Polyethnic Nature of Mindfulness in Relation to Error Monitoring," Association for Psychological Science, 24-27 May 2018.
- Petrescu, I. "Examining Changes in Expression of Orange Carotenoid Protein Homologs in *Fremyella Diplosiphon* in Response to Nutrient-deprived Conditions," National Conference on Undergraduate Research, 11-13 April 2019.
- Pezeshkian, K. "1) Blood Pressure Variation and Renal Function Changes in Chronic Renal Insufficiency Patients with or Without Diabetes In A Large Cohort Study. 2) Genetic Polymorphisms Associated with Apparent Treatment-Resistant Hypertension in Patients with Chronic Kidney Disease," American Heart Association Hypertension Scientific Sessions, 5-7 September 2019.

- Roehler, R. "Tools for Empowerment Using Social-Emotional Learning for the Academic and Character Development of Lansing Youth," National Council for Black Studies 43rd Annual Conference, 6-9 March 2019
- Sappe, M. "The Impact of Marijuana on the Lodging Industry," The REPS 2019, 12-13 April 2019.
- Schultheiss, H. "Sensor Technology to Measure Social Interactions of Children with Autism Spectrum Disorders," CEC-DADD Conference on Autism, Intellectual Disability & Developmental Disabilities, 16-18 January 2019.
- Smolinski, A. "Scalar Implicatures: Formal and Experimental Exploration," Italy Workshop, 11-13 July 2018.
- Spencer, A., Smith, A., Ring, M. Moreau, G., Brook, E. Joint Program for Initiative Collaborated with Professor Caballero in Ghana, 12-23 May 2019.
- Stacey, R. "Scalar Implicatures: Formal and Experimental Exploration," Italy Workshop, 11-13 July 2018.
- Van Haaren, K. "A Story of Customer Delight: From American and Chinese Perspective," Asia Pacific & ERO CHRIE Youth Conference, 22-23 May 2019.
- Vesikar, Y. "Reference Point Based NSGA-III for Preferred Solutions," IEEE 2018 Symposium Series on Computational Intelligence, 18-21 November 2018.
- Walter, D. "Do Differences Exist in Sedentary Activity Between Children with Autism Spectrum Disorder and Down Syndrome?," National Federation of Adapted Physical Activity Symposium, 1-3 October 2018.
- Wood, A. "Investigating the Neural Basis of Aesthetic Pleasure in Reading," National Conference on Undergraduate Research (NCUR), 4-7 April 2018.
- Zarger, R., Zhou, W., Young, K., Shereda, J. "An Agricultural Tool, and Then Some," TMS 2019 148th Annual Meeting & Exhibition, 10-14 March 2019.

About the Contributors

Emma Bignall completed a bachelor's degree in anthropology and minor in Spanish at Michigan State University in 2019. During her time at MSU, she worked with her professor, Dr. Masako Fujita, and Graduate Research Assistant, Nerli Paredes Ruvalcaba, in the Biomarker Laboratory of Anthropological Research. This research focuses on maternal health and socioeconomic status in Northern-Kenya and led to a presentation opportunity at the American



Association of Physical Anthropologists Conference in 2019. She also enjoyed studying abroad in Puerto Rico and Ecuador while living with host families. Emma's future plans include pursuing a Master of Science in Physician Assistant Studies.

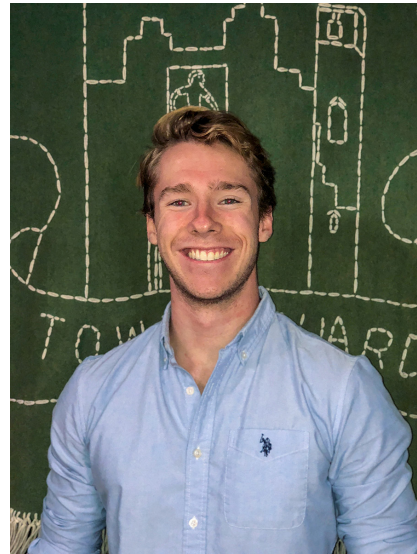
Alena Bowman is an Honors College senior at Michigan State University. She is majoring in Environmental Biology/Zoology in the Lyman Briggs College with minors in Spanish and Conservation, Recreation, and Environmental Enforcement. She



currently works as a member of the education team at the MSU Museum, a consultant at MSU's Writing Center, and a learning assistant for Honors Organismal Biology. During her time at MSU, she has been on the executive board of MSU's Zoological Students Association and MSU Science

Theatre. Her favorite topics to learn and teach about are natural history, ecology, and conservation. After graduation, she plans to pursue a career in education and science communication.

Paul Clancy is an Honors College senior, with double majors in Neuroscience and Physiology (College of Natural Science) as well as a minor in



Global Public Health and Epidemiology. While working in Dr. McAuley's TAP lab, he has been involved in a few projects whose research interests lay primarily in perception of various auditory effects, including language and speech. In addition, this year he

has stepped up as the Social Media Chair of the lab, running a variety of social media accounts. He is also involved in American Medical Student's Association (AMSA) as well as Ski Club. Upon graduation, Paul plans to continue his academic success by attending medical school.

Dev Dayal is a senior from Toronto, Ontario studying Human Biology through the Lyman Briggs



College and the Honors college. Dev is also member of the Osteopathic Medical Scholars Program and works as a Diversity, Equity, and Inclusion (DEI) Intercultural Aide (ICA) on campus. Dev not only has a strong passion for and interest in the field of medicine,

but he also has a passion for writing poetry. Dev has won 8 Canadian national poetry competitions and has been published in numerous anthologies that can be found in all major Canadian libraries. He plans to attend medical school while continuing to write and publish his work.

Sarah Dec is an Honors College and Social Science Scholars graduate who completed a bachelor's degree in psychology in May 2019. While attending MSU,



she worked in the Timing, Attention, and Perception lab on projects involving the evaluation of speech, music, and attention phenomena in the context of cognitive psychology and neuroscience. During her time with the lab she enjoyed count-

less opportunities to work closely with research teams to present and publish scientific work. Her passion for science and interest in the mind lead her to the University of Maryland where she is currently studying industrial/organizational (I/O) psychology as a master's student. She plans to continue her pursuit of psychological expertise as a practicing I/O professional.

Audrey Drotos received a B.S. in Neuroscience and B.A. in Music from Michigan State University.



There, she studied auditory cognition and music perception under the direction of Dr. Devin McAuley. She is currently pursuing a Ph.D. in Neuroscience at the University of Michigan where she studies auditory circuitry in Dr. Michael

Roberts' lab. Outside of academia, she enjoys backpacking, spending time with family and friends, and reading.

Sameed Khan is an Honors College junior studying Computer Science and Human Biology in the Lyman Briggs College. His writing interests center on poetry and the exploration of the human narra-



tive. His work aims to bring the reader to a place where the emotions, thoughts and feelings of the subject can be experienced. His goal is to use poetry to connect people across borders through their stories, and, in doing so, bring about empathy for the marginalized

and ignored. Beyond writing poetry, he also works as a research assistant for the Arora Lab at the Institute for Quantitative Health Science and Engineering and is a member of the Osteopathic Medical Scholars Program.

Camellia Landman is a senior English Creative Writing major at Michigan State University with a history minor and a science cognate. She is a student editor for ReCUR as well as a film reviewer for



Agnes Films. She also reviews books with her friends on Instagram (@thelastbookbenders). After graduation, Camellia intends to pursue a graduate degree in museum and culture studies as well as a

career as a writer. She has always had a passion for stories and would love nothing more than to help them be told, whatever form they may take.

Anusha Mamidipaka is a sophomore majoring in Neuroscience in Lyman Briggs College and Psychology in the College of Social Science and minoring in Graphic Design in the College of Arts



& Letters. Her research interests include exploring the factors that affect speech understanding in difficult listening conditions. She is also interested in investigating how people narratively perceive instrumental music. She is a member of MSU brushstrokes,

the mural painting club on campus, and currently is the Art Editor of Red Cedar Review, MSU's oldest creative writing journal. She plans to pursue medical school after undergrad and become a physician.

Racheal Chris Nassimbwa is an Honors College senior majoring in Medical Laboratory Science with a minor in Global Public Health and Epidemiology. She spent her 2019 summer in



Malawi working with Dr. Karl Seydel at the Blantyre Malaria Center. There, she worked on a research project to develop a quantitative assay for measuring total parasite load among malaria patients. She presented this work at the 2020 National Collegiate Research

Conference at Harvard University. Racheal is currently working in another research lab on campus where she is studying HIV accessory genes and their effect on the immune system. Upon graduation, Racheal plans to pursue work as a Clinical Laboratory Scientist and later continue her academic success in graduate school to pursue a doctorate in Infectious Diseases and Immunology with an integration of Public Health.

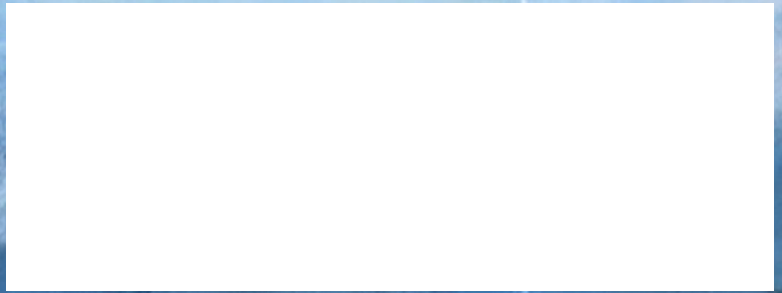
Benjamin Raab is a senior double majoring in Political Theory and Constitutional Democracy in James Madison College and History in the College of



Social Science with a minor in European Studies. Ben is a member of the Honors College and a Social Science Scholar. Ben is completing a two-year Professorial Assistantship with Dr. Emily Tabuteau in which he is researching medieval history.

Ben is also a member of the Honors College Dean's Advisory Council. Upon completion of his undergraduate studies, Ben plans to attend law school.

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