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Math Anxiety in Deaf, Hard of Hearing, and Hearing Students: Antecedents and Outcomes

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Abstract

Math anxiety, or the feeling of apprehension in the face of math, impedes success in the subject. A global problem affecting all age groups, math anxiety can cause short-term distress and long-term avoidance of science, technology, engineering and math (STEM) careers. Math anxiety may be an underlying reason that deaf and hard of hearing individuals are significantly underrepresented in the STEM workforce. This study aims to understand the development and consequences of math anxiety in deaf, hard of hearing, and hearing university students via an online questionnaire. One hundred thirty-six deaf and hard of hearing students and 162 hearing students (total n=298) reported their math anxiety levels, general anxiety levels, perceptions about STEM, career aspirations and other factors (e.g., parents' attitudes towards math, school experience, hearing status, etc.). The study first aimed to evaluate which factors predict math anxiety. Using a multiple linear regression, we found that age, hearing status, school environment and parental attitudes about math were all significant predictors of math anxiety. We then asked whether these same factors, along with parental involvement in STEM, influenced the likelihood of students' majoring in STEM. A logistic regression found that only age and parental involvement in STEM were significant predictors of majoring in STEM fields. This paper hopes to discern the antecedents of math anxiety in an attempt to close the existing gap between deaf and hard of hearing individuals relative to hearing individuals in STEM fields.

Introduction

The prevalence of anxiety disorders, particularly in adolescents and young adults around the world, has been studied in depth. In educational settings, math anxiety is without a question the most prevalent type of anxiety disorder (Luttenberger, Wimmer & Paechter, 2018). Math anxiety is defined as “an adverse emotional reaction to math or the prospect of doing math” (Maloney & Beilock, 2012). As a problem that has presented itself around the world across all ages, math anxiety has recently come to the attention of researchers in psychology, education, and child development. Math anxiety is pervasive and persistent; it can affect daily tasks (e.g. reading a cash receipt) and can arise in early childhood and last well into adulthood (Maloney & Beilock, 2012). Math anxiety can have the short-term effect of negatively impacting performance in school, and a long-term effect of influencing one’s career choices (Luttenberger, Wimmer & Paechter, 2018).

A majority of adolescents reported experiencing tension and worry when confronted with math in the international assessments of the PISA (Programme for International Student Assessment) (Luttenberger, Wimmer & Paechter, 2018). Not only do math-anxious students take fewer math classes, but they also learn less in the ones that they take (Beilock & Maloney, 2015). math-anxious students feel negative emotions when confronted with math, and this limits their working memory capacities. In essence, highly math-anxious students are preoccupied with two things at once when confronted with a math problem; their anxiety, and the problem itself. Less of their brain’s resources can be directed towards solving the problem at hand, and accordingly their math performance suffers as compared to less math-anxious students who can direct more of their brain’s capacities to the math itself (Beilock & Maloney, 2015). Highly math-anxious students are therefore caught in a self-fulfilling prophecy in which their anxiety limits their achievement in math, which further increases their math anxiety.

Math anxiety can push students away from pursuing careers in science, technology, engineering and mathematics (commonly known as STEM). Math anxiety hinders math achievement (Ramirez, Chang, Maloney, Levine & Beilock, 2016), an essential attribute students consider when deciding to pursue careers in STEM (National Science Board, 2010). Given the national efforts to increase participation and success in STEM careers, it is important to ensure students' mathematical abilities are not being disrupted. Specifically, attention should be shifted to populations that are at present underrepresented in STEM careers, such as the deaf and hard of hearing population (DHH). The portion of DHH people in STEM careers is miniscule as compared to the percentage of the general population; DHH people comprise 0.13-0.19% of STEM disciplines while the general population comprises 11-15.3% (Solomon, 2012).

Little research has been conducted on effective teaching and learning strategies for DHH students; math anxiety in DHH students is even less researched. Improving the retention of DHH individuals in STEM benefits both the DHH and STEM communities. Access to equal educational and career opportunities should not be determined by one's hearing status. Additionally, diversity and inclusiveness in STEM research has been shown to improve the quality of the science produced (Braun et al., 2018). Math anxiety limits achievement in math, and this study aims to identify one barrier DHH students may face in academic success in the hopes of helping to remove that barrier.

Math anxiety can be regulated and reframed, which can lead to greater academic success (Beilock & Maloney, 2012). Understanding the factors that lead to math anxiety developing in students is key to developing preventative measures.

Challenges DHH students may face in education

Deaf and hard of hearing students face myriad challenges in educational settings (Braun et al., 2018). They may be assigned less challenging projects in their classrooms as compared to hearing students because of a lack of confidence that more challenging tasks can be explained and understood in the language DHH students prefer. DHH students may also face assumptions of being poorly educated or inherently less intelligent (e.g. DHH individuals may be asked if they can read and write English). DHH students who request interpreters may face insensitive comments about interpreters being "distracting" (Braun et al., 2018). Requesting interpreters often presents its own hassle, especially in STEM. DHH students who are involved in research (as many undergraduate and graduate students are) often must spend extra time with the interpreter to explain the scientific vocabulary relevant to their projects. They may have to do this more than once per week, depending on the number of times a different interpreter is provided to them (Solomon, Braun, Kushalnagar, Ladner, Lundberg, Painter & Nuzzo, 2012).

Another unique barrier DHH students may face with interpreters (and also with real-time captioning) is lag time. Regardless of rate of speech, DHH students requesting interpreters will experience a lag time of up to 10 seconds when interpreting from spoken English to ASL. This may mean that DHH students miss more information and have fewer chances than hearing students to ask questions or participate in class. Furthermore, DHH students deal with greater cognitive load than their hearing counterparts because they must constantly shift focus between the interpreter, the professor and the content. That interpreting and real-time captioning often contain errors also adds to a DHH student's increased cognitive load in class (Braun et al., 2018).

Another noteworthy point is that DHH individuals vary in their backgrounds, culture, hearing status and other variables. There is no one-size-fits-all method of instruction for DHH students, contrary to what some faculty and educational administrators may think. DHH individuals vary widely in the methods of communication they prefer, in their learning styles, and in the accommodations they need (Braun et al., 2018).

As such, DHH individuals must often work harder to achieve the same opportunities as other students. Feeling accepted by the STEM community is essential to the retention of individuals in these fields, but DHH individuals often feel unwelcome in educational and research settings due to the discrimination they too often face. DHH individuals may also feel uncomfortable in requesting accommodations, leaving them at a disadvantage compared to their peers (Braun et al., 2018).

Current Study

Given the prevalence of math anxiety, the current study hopes to add to the evidence on how and why math anxiety develops. In particular, the importance of language, school environment and basic cognition are just a few of the variables that have yet to be studied in depth for their connections to math anxiety. Perhaps most importantly, this study aims to determine how math anxiety develops in people who are DHH, and whether that contributes to their disproportionate representation in STEM careers.

Ariapooran (2016) compared math anxiety, motivation in math, and math performance in female DHH and hearing middle school and high school students and found higher math anxiety in the DHH students. The current study also assesses differences between DHH students and hearing students in their math anxiety levels and goes one step further. We hope to determine how math anxiety impacts students' feelings about and performance in math in educational settings. Additionally, we hope to see if these attitudes persist long term and do impact students' vocational choices as has been found in the literature (Luttenberger, Wimmer & Paechter, 2018).

The current study evaluates numerous variables that may give rise to math anxiety, such as the attitudes of teachers and professors. In 1999, Jackson and Leffingwell found that students internalize their instructors' attitudes towards math all the way from kindergarten to college. In fact, the negative memories associated with math classes (indeed, only 7% of the students in their sample reported positive experiences in math classes) were so strong that math anxiety could persist for *more than two decades* (Jackson & Leffingwell, 1999). This study asks students to indicate how much emphasis is placed on STEM in their schools to understand the role schools and instructors play in their students' math anxiety and performance.

Another potential antecedent to math anxiety that the current study explores is the impact parents have on their children's levels of math anxiety. Prior literature indicates that if parents with high levels of math anxiety frequently help their children with math homework, their children will have more anxiety and have learned significantly less math by the end of the school year. This relationship was not found if parents reported helping their children with math homework less frequently (Maloney, Ramirez, Gunderson, Levine & Beilock, 2015). It was important to know if this trend existed in college-aged students as well, and how it differed in DHH students as compared to hearing students.

Recognizing what gives rise to math anxiety is important, but perhaps not as important as understanding how to diminish it in students. The reason for this is that math anxiety, in addition to hindering a students' academic success, can also limit the types of careers they feel qualified for. Math-anxious students not only elect to take fewer math classes but also classes in the related fields of engineering, science and technology. Furthermore, when students were asked in a study to choose careers in various fields, math anxiety was a crucial factor for students who excluded careers in science and engineering. The students' career decisions hinged more so on their math anxiety and interest than they did on their knowledge in math (as measured by their score on the Scholastic Assessment Test, or SAT) (Luttenberger, Wimmer & Paechter, 2018).

We deemed that all of these findings were important to evaluate in the current study, and tried to encompass as many variables as possible when creating our main questions. This study's overarching questions were:

1. What differences exist between hearing and DHH students regarding STEM (i.e., do DHH report more math anxiety compared to hearing)?
2. How do parents' attitudes about math and students' experiences at home surrounding math influence students' feelings about and achievement in math?
3. How do experiences and access to resources in school affect students' attitudes about and performance in math?
4. Is the likelihood of studying or working in STEM fields impacted by perceptions about the importance of math and math anxiety?

An anonymous online questionnaire examining the above questions was distributed to college-aged hearing and DHH students. Hearing students received the questionnaire in written

English, and DHH students could view it in American Sign Language (ASL) or English. This questionnaire gathered information on students' math anxiety levels with the use of the standardized Abbreviated Mathematics Anxiety Rating Scale, commonly known as the A-MARS (Richardson & Suinn, 1972). To assess basic cognition, participants completed a test called Panamath (panamath.org), which measures approximate number sense (ANS) aptitude and number sense (Halberda, Mazzocco & Feigenson, 2008). Similar to guessing the number of beans in a jar, participants look at two sets of dots and determine which set has more. Participants also reported their general anxiety levels using the Generalized Anxiety Scale 7 (GAD-7), a frequently used diagnostic self-report questionnaire for assessing anxiety disorder (Löwe, Decker, Müller, Brähler, Schellberg, Herzog & Herzberg, 2008).

Other variables assessed by the questionnaire included: demographics, parental attitudes towards math, school environments and performance in STEM classes. For instance, participants indicated if and how their parents helped them with their math homework. Participants also specified which languages they used at home and at school, how important they believed achievement in STEM was and their career aspirations. Throughout the questionnaire, we asked participants these questions in two timeframes: when they were growing up and currently.

The resulting dataset is quite extensive and rich, and allows many questions to be addressed. This thesis focused on the following subset of questions and posited the following hypotheses.

1. **Does age, hearing status, school environment and parental attitudes towards math predict students' math anxiety?**
    a. **Hypotheses**

i. Age will not predict students' math anxiety.

ii. DHH students will report higher levels of math anxiety than hearing students.

iii. Professors and schools that place less emphasis on STEM by providing fewer resources and less support (e.g. STEM faculty are not accessible) will have students who are more math-anxious.

iv. Students will report higher levels of math anxiety if their parents show significant negative emotionality and attitudes when presented with math.

2. **Is the likelihood that a student will choose a STEM major influenced by their age, hearing status, school environment, parental attitudes towards math and parental involvement in STEM careers?**

   a. **Hypotheses**

i. Age will not predict the likelihood that a student will major in STEM.

ii. DHH students will be less likely to major in STEM than hearing students.

iii. Professors and schools that place less emphasis on STEM by providing fewer resources and less support (e.g. STEM faculty are not accessible) will have students who are more math-anxious.

iv. Students will be less likely to major in STEM if their parents show significant negative emotionality and attitudes when presented with math.

v. Students will be more likely to major in STEM if at least one of their parents has a career in STEM.

Method

Participants

The participants were 298 students (160 female) from the University of Connecticut (UConn) and Gallaudet University (Table 1). The average age of students was 20.2 years (*SD*=1.92), with the oldest participant being 30 years old. The average age for deaf students was a little higher at 21.2 years (*SD*=2.11), whereas hearing students on average were 19.4 years old (*SD*=1.28). The number of female deaf participants was a little more than half the number of male deaf participants. Conversely, more than two times as many female hearing students participated in the study as male students. Non-binary individuals comprised less than one percent of the entire sample. The average socioeconomic status (SES), as measured by the Barratt Simplified Measure of Social Status (Barratt, 2005), of hearing students (*M*=48.9, *SD*=11.3) was slightly above the average of the entire population (*M*=46.1, *SD*=12.5). The SES of DHH participants (*M*=42.3, *SD*=13.1) was slightly lower than the average for the entire population.

Fifty-five participants (15.5%) were excluded for the following reasons: 36 participants recorded only partial responses and the remaining 19 participants had discrepancies in the match between hearing status and the school they attended. We recruited DHH students from Gallaudet University, but three Gallaudet students were hearing. We recruited hearing students at UConn, but 12 students did not indicate their hearing status, three students were hard of hearing and one student was deaf. These students were excluded for the purposes of this paper to allow for more accurate comparisons between deaf and hearing students.

	Total (n=298)	**Deaf** (n=136)	**Hearing** (n=162)
Age (years)	M=20.2 (SD=1.92) *18-30*	M=21.2 (SD=2.11) *18-30*	M=19.4 (SD=1.28) *18-24*
Gender			
Female	160 (53.7%)	48 (35.3%)	112 (69.1%)
Male	136 (45.6%)	88 (64.7%)	48 (29.6%)
Non-binary	2 (0.7%)	0 (0%)	2 (1.3%)
Race			
White	221 (74.2%)	124 (91.2%)	97 (59.9%)
Underrepresented	73 (24.5%)	9 (6.62%)	64 (39.5%)
Not applicable	4 (1.3%)	3 (2.18%)	1 (0.6%)
Ethnicity			
Hispanic or Latino	23 (7.72%)	7 (5.15%)	16 (9.88%)
Not Hispanic or Latino	261 (87.6%)	125 (91.9%)	136 (84.0%)
Prefer not to answer	11 (3.69%)	3 (2.21%)	8 (4.94%)
Unsure	3 (0.99%)	1 (0.74%)	2 (1.18%)
SES (3-66)	M=46.1 (SD=12.5) *11-66*	M=42.3 (SD=13.1) *14-64.5*	M=48.9 (SD=11.3) *11-66*

Table 1. Demographic characteristics of the sample.

Materials

The two questionnaires assessing the research questions were designed using the UConn Qualtrics website. The questionnaires were anonymous and took 30 minutes to complete. The target population for the first questionnaire was hearing students, and the target population for the second questionnaire was DHH students. Though the content and questions asked of the questionnaires were the same, the two versions differed only in the language they used (English or ASL), and, as described below, the type of device permitted to be used by participants.

Hearing Version[1]

This version of the questionnaire was distributed to students at UConn. Eligibility requirements for this version of the questionnaire were as follows: at least 18 years old, and a college student. Participants could complete the questionnaire on their mobile phones or on their desktop computers/laptops. Even though the target population was hearing students, hearing ability was not listed as part of the eligibility requirements because the DHH population at UConn is so small (though some deaf and hard of hearing students did fill out the questionnaire and were subsequently not included in analyses). The primary method of recruitment was the UConn Participant Pool, a system administered by the UConn Psychological Sciences department that grants credits for completing studies. Students received one credit if they signed up and completed the questionnaire through the Participant Pool.

Students were also recruited via social media and community contacts. These students did not receive credit for completing the questionnaire, either because they did not sign up through the UConn Participant Pool site, or because they were ineligible to receive credit.

[1] Here is a link to the PDF version of the questionnaire that was distributed to hearing students: https://documentcloud.adobe.com/link/track?uri=urn:aaid:scds:US:a106d5d9-1eca-4361-8fd7-b8922cefc1ac

***DHH Version*[2]**

DHH participants were recruited primarily from Gallaudet University, a private university in Washington, D.C. federally chartered for educating DHH students. The eligibility requirements mandated that participants were either deaf or hard of hearing, at least 18 years old, and enrolled as a college student. Participants were only allowed to complete the questionnaire on their laptops or desktop computers because the entire ASL video frame did not fit on a standard phone screen. Recruitment was primarily accomplished with the help of faculty at Gallaudet and social media. As was the case with the hearing version of the questionnaire, students at other universities besides Gallaudet were eligible to complete the survey, given that they met the other eligibility requirements.

Students who completed the DHH version of the questionnaire received monetary compensation in the form of a $15.00 Amazon gift card. One of the reasons for the difference in compensation between the two populations is that the deaf and hard of hearing college student populations are significantly smaller than the hearing college student population. Second, DHH students, especially at Gallaudet, are asked to participate in an overwhelming number of research studies and accordingly experience much more research fatigue. Monetary compensation was necessary to make the study more attractive to DHH students and to ensure that DHH recruitment goals were met.

Another key difference between the hearing and DHH versions of the questionnaire is that the DHH version was also available in ASL (recruitment materials were also provided in ASL). Each question and answer set was accompanied by its own ASL video; participants

[2] Here is a link to the PDF version of the questionnaire that was distributed to DHH students: https://documentcloud.adobe.com/link/track?uri=urn:aaid:scds:US:6bd581ee-e72a-4f9a-a80a-2f5aa273d3b9

simply had to click on the text of the questionnaire, and the corresponding ASL video would appear in a new tab. A deaf signer produced the ASL versions and the videos were also reviewed by a proficient ASL user.

Procedure

The hearing and DHH versions of the questionnaire resembled one another largely in content. Both began with the informed consent, after which participants had to indicate if they wanted to participate in the study. Participants then completed the Panamath cognitive test in which they saw a number of blue dots on one side of their screen, and a number of yellow dots on the other side (Figure 1). To incorporate the dot arrays into the Qualtrics questionnaire, videos of each individual dot array were created and then presented to the participant for approximately half a second. Participants guessed if there were more blue dots or more yellow dots. Typically, Panamath is administered to children and has predicted or correlated with math ability at the elementary level, dating back to scores on standardized tests from kindergarten (Halberda, Mazzocco & Feigenson, 2008; Mazzocco, Feigenson & Halberda, 2011). Even after controlling for language abilities, spatial processing ability, working memory, IQ and executive function, Halberda, Mazzocco and Feigenson (2008) still found a significant positive correlation between a child's mathematics ability and their visual approximation ability of numerosity.

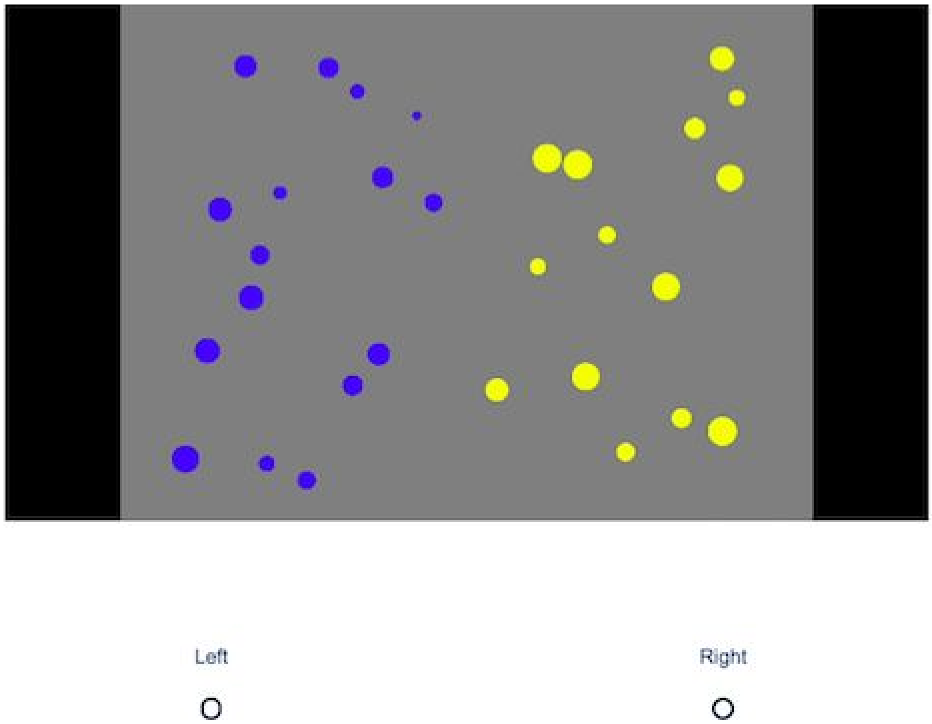


Figure 1. An example of a trial from Panamath. After seeing this display flashed on their screen for less than a second, participants had to indicate which side had more dots.

However, a study looking at 80 college-aged students from Beijing failed to find the same correlation between non-symbolic numerical processing (assessed with tasks similar to Panamath) and performance in advanced mathematics. The same study, though, did find cognitive measures of spatial processing and language abilities to correlate with performance in advanced mathematics performance (Wei, Yuan, Chen & Zhou, 2012). Panamath was included in this questionnaire for two reasons. First, it acted as a control measure. Second, it was included to see whether ANS scores were related to students' performance in STEM courses.

After completing Panamath, participants filled out the Demographics portion of the questionnaire. Participants were asked to indicate their hearing status. Students who indicated they were DHH were then prompted with questions about hearing technology; students who were hearing skipped those questions. Then, all students indicated which languages were used in their homes and schools growing up, and which ones were used currently in both the home and school contexts. Knowing which languages the students grew up with and which they are currently exposed to is important because when DHH children are exposed to languages they are less comfortable with, their learning can be delayed.

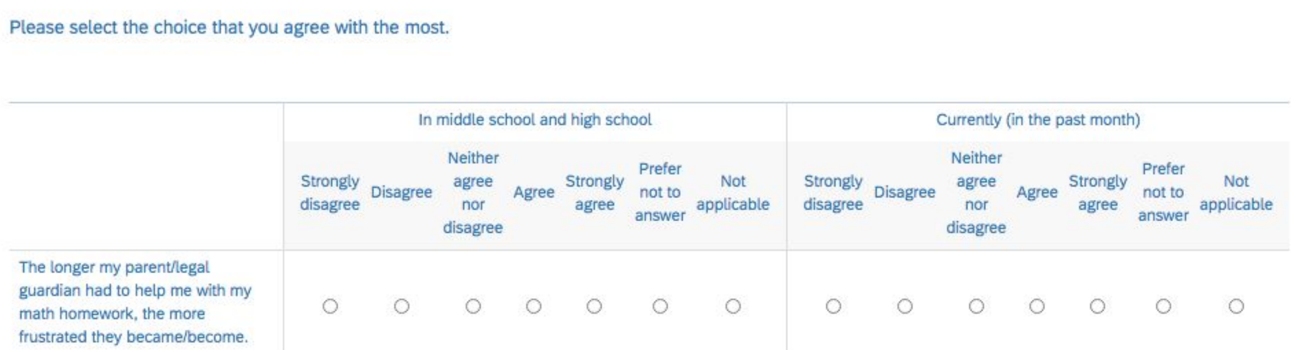
The next section was called “Parental Questions”, which asked participants to indicate the hearing status of their parents and/or legal guardians. We asked this question to get an understanding of why a particular language would have been used at home, particularly for DHH students (e.g. some hearing parents may only speak English at home even if their DHH child prefers ASL).

Participants afterwards answered questions about their education level and desired occupations. They were also asked to indicate the highest degree attained by their parents, and their parents’ occupations. The purpose of these questions was to assess the influence of parents’ education levels and chosen occupations on the likelihood of their children pursuing a career in STEM.

Participants reported their general anxiety levels by answering the GAD-7 (Löwe, Decker, Müller, Brähler, Schellberg, Herzog & Herzberg, 2008). Prior research has only rarely has math anxiety been linked to clinical anxiety disorders (Luttenberger, Wimmer & Paechter, 2018). The GAD-7 (Löwe, Decker, Müller, Brähler, Schellberg, Herzog & Herzberg, 2008) was therefore included to evaluate whether general anxiety levels were in any way correlated to levels of math anxiety. Next, participants filled out the 25-item A-MARS (Mathematics Anxiety Rating Scale, Richardson & Suinn, 1972). This scale was adapted from the original 98-item

Mathematics Anxiety Rating Scale published by Richardson and Suinn, which had been the major measurement tool of mathematics anxiety used in research and clinical studies since 1972. The A-MARS is a 25-item scale that presents situations in both educational and non-educational settings that might elicit math anxiety. Some examples of the items include: “Studying for a math test”, “Walking into a math class” and “Reading a cash register receipt after your purchase”. Participants additionally answered questions that gauge whether participants find math to be important and useful to their lives. Scores on the A-MARS range from xx-yy; higher scores indicate a higher level of math anxiety.

Participants then reported how their parents approached the topic of math with them growing up, and how they approach math now. One example of the many questions that examined parents’ attitudes and feelings towards math are shown in Figure 2. This question and others like it addressed both of our research questions about math anxiety levels and the probability of studying STEM in university.


Please select the choice that you agree with the most.

	In middle school and high school							Currently (in the past month)						
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Prefer not to answer	Not applicable	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Prefer not to answer	Not applicable
The longer my parent/legal guardian had to help me with my math homework, the more frustrated they became/become.	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Figure 2. An example of an item from the questionnaire. This question aims to understand how parents feel about math. Other questions ask about certain behaviors parents showed when helping with math homework, such as raising their voice in anger.

Finally, participants indicated their level of agreement with various statements evaluating their school environments growing up (e.g. grade school) and currently (e.g. university). An important question in this section asked whether math instruction is provided in a manner that deaf and hard of hearing students are comfortable with. This section also asks whether schools that place more emphasis on STEM (science, technology, math and engineering) subjects have students with higher performance in math. The purpose of this section of the questionnaire is to understand how school environments and instructors influence students' math anxiety levels. Maloney and Beilock (2012) explained that teachers impart their anxiety in their own math abilities to their students, resulting in children learning less. Maloney and Beilock saw this in children in elementary school, but the effect persists in university too. The following caused such strong negative dispositions towards math that math anxiety persisted for decades in students: teachers making derogatory comments when students didn't understand math, teachers refusing to help, teachers rushing through the lesson, and teachers avoiding eye contact and proximity with students (Jackson & Leffingwell, 1999).

The study ends with the debrief, after which participants taking the DHH version of the questionnaire provide their emails through a separate link for compensation purposes.

Results and Discussion

First, we examined if the following variables predicted students' math anxiety levels (measured by A-MARS scores): age, hearing status, school environment and parental attitudes towards math. We predicted that age would not predict math anxiety, but hearing status, school environment and parental attitudes would. We ran a multiple linear regression, the results of which are shown below in Figure 3.

	Estimate	Standard Error	t-value	p-value
Intercept	96.67	18.35	5.27	**2.69×10^{-7}*****
Age	-1.82	0.78	-2.34	**0.020***
Hearing Status (Hearing)	-23.50	4.33	-5.42	**1.24×10^{-7}*****
School Environment	0.41	0.18	2.27	**0.02***
Parental Attitudes	0.61	0.27	2.31	**0.02***

Figure 3. Results from multiple linear regression with A-MARS scores as the outcome variable ($p < 0.05$ *, $p < 0.01$ **, $p < 0.001$ ***).

Age was a significant predictor of students' math anxiety levels ($\beta = -1.82$, $p = 0.02$, Figure 3). Older students scored lower on the A-MARS which means that they were less math-anxious as compared to younger students. This finding is inconsistent with our original hypothesis. One reason for this could be that general anxiety levels tend to increase with age, particularly in adolescents (Kozina, 2013). A larger cross-sectional, two wave cohort study for anxiety conducted by Kozina (2013) on 10 year olds and 14 year olds found that the 14 year olds showed higher levels of anxiety than 10 year olds. The results of the GAD-7 (Löwe, Decker, Müller, Brähler, Schellberg, Herzog & Herzberg, 2008) were not analyzed in this study but could explain these results.

Our findings indicated that hearing students were significantly less math-anxious compared to deaf students ($\beta = -23.50$, $p < 0.001$, Figures 3 and 4). As Figure 5 shows, the average A-MARS score for deaf students was nearly 30 points higher than hearing students' scores. This finding was consistent with our hypothesis and with prior literature, such as the study by Ariapooran (2017), which found that DHH female students were more math-anxious than hearing female students.

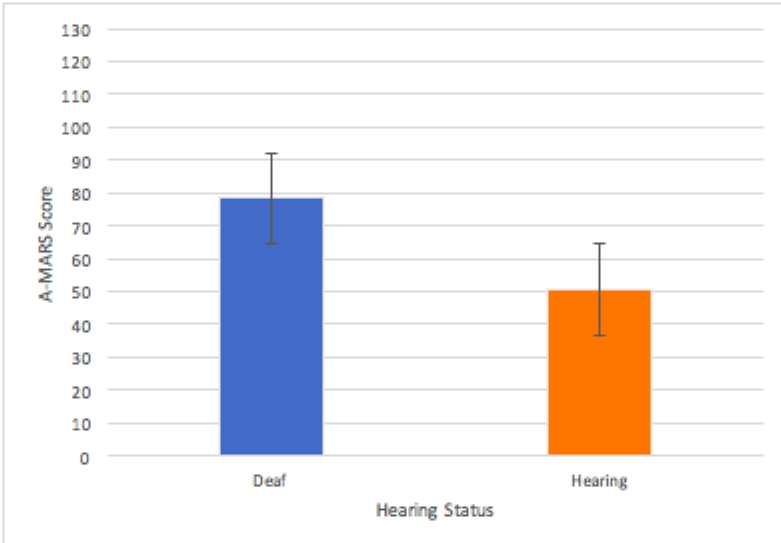


Figure 4. A-MARS Scores by Hearing Status. Deaf (*M*=78.3, *SD*=18.0) students scored higher on the A-MARS (i.e., reported more math anxiety) than hearing students (*M*=50.7, *SD*=26.7). Error bars represent standard error.

Participants were asked their level of agreement on various questions about the level of support and access to appropriate resources their schools and instructors provide regarding STEM courses. Figure 5 shows the questions students had to respond to. For this paper, only the responses to "In my current university" (right column) were analyzed. To summarize the school environment, each answer was scored on a scale of 1-5, with 1 corresponding to "Strongly disagree" and 5 corresponding to "Strongly agree" ("Prefer not to answer" and "Not applicable" were coded as N/A). These questions assessed the importance of STEM classes, the quality of STEM instructors and the accessibility and quality of resources in school. Students' responses to all seven questions were scored and summed, which represents the independent variable on the scatterplot in Figure 6. A higher score indicated an educational environment with greater support for their students in STEM subjects. As such, we hypothesized that the higher the student scored their school environment, the lower that student's A-MARS score would be.

Please indicate your level of agreement with the following statements regarding STEM (science, technology, engineering and math).

	In middle school and high school							In my current university (in the past month)						
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Prefer not to answer	Not applicable	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Prefer not to answer	Not applicable
STEM was/is very important/emphasized by my school.	○	○	○	○	○	○	○	○	○	○	○	○	○	○
The faculty in STEM were/are available and approachable.	○	○	○	○	○	○	○	○	○	○	○	○	○	○
STEM faculty readily provided/provide help with homework and/or assignments.	○	○	○	○	○	○	○	○	○	○	○	○	○	○
My professors in STEM provided/provide instruction and in the languages I prefer (e.g. English, ASL, SimCOM, SEE, Cued Speech, CART, etc.).	○	○	○	○	○	○	○	○	○	○	○	○	○	○
My school provided/provides resources outside of the classroom to help with STEM homework/assignments (e.g. tutoring).	○	○	○	○	○	○	○	○	○	○	○	○	○	○
The resources in STEM my school provided/provides are well known to most students.	○	○	○	○	○	○	○	○	○	○	○	○	○	○
My school provided/provides resources in STEM in the languages that I prefer (e.g. English, ASL, SimCOM, SEE, Cued Speech, CART, etc.).	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Figure 5. Students responded to these questions to indicate how supportive their school environment was of STEM.

School environment was a significant factor in predicting math anxiety ($\beta = 0.41$, $p = 0.02$, Figures 3 and 6). However, these findings refuted our original hypothesis that higher school environment scores would correspond with lower scores on the A-MARS. Students still reported high levels of math anxiety even when they experienced higher levels of support and positive emphasis on STEM subjects at their universities . One reason for this could be that students enrolled in schools that provide more support and resources in STEM also face more competition from their peers to succeed in those STEM classes. The accessibility of resources and faculty in STEM may allow all students to have greater success in STEM. Students may also attribute more importance to doing well in STEM, a possibility in line with Jackson and Leffingwell's (1999) findings that students internalize their professor's attitudes about math. As such, students may feel under more pressure to perform at a high level in STEM classes, and subsequently experience more math anxiety.

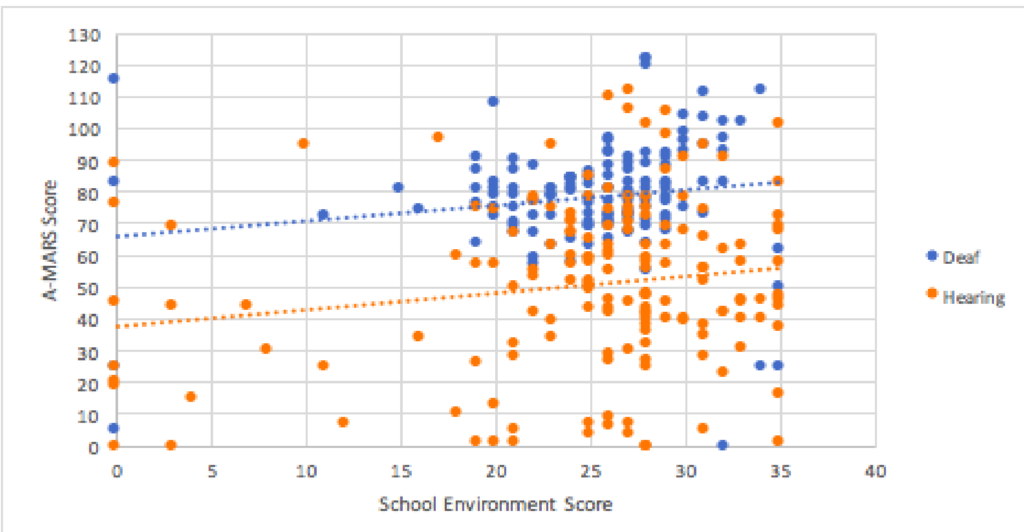


Figure 6. A-MARS Scores by School Environment. The average school environment scores for deaf (*M*=25.1) and hearing (*M*=24.8) students were almost identical even though the average math anxiety scores were vastly different.

To assess parental attitudes towards math, students specified how their parents behaved while helping them with their math homework in the past month (for this paper, data from students' experiences with parents growing up were not included in the analyses). They indicated how stressed their parents appeared to be, how often they raised their voices in anger and finally, if their parents appeared more frustrated as time went on. For the purposes of these analyses, three questions about parental attitudes were scored on a scale from 1-5. We summed up the scores to provide a summary of parental attitudes towards math; the higher the parental summary score, the more negative the attitudes of the parent were towards math.

As such, we hypothesized that higher parental summary scores would predict higher A-MARS scores in students. In other words, the more negative a student's parents' attitudes were towards math, the more math-anxious they would be. Our findings were consistent with our hypothesis and parental attitudes towards math were found to be significant predictors of math anxiety levels ($\beta = 0.61$, $p = 0.02$, Figures 3 and 7). Maloney, Ramirez, Gunderson, Levine and Beilock showed in 2015 that the children of parents who were highly math-anxious and frequently helped with homework would have greater math anxiety by the end of the academic year. Even though our study did not measure math anxiety in parents directly, negative emotionality towards math is an indicator of it. Other studies have also shown the importance of parents in their children's math achievement at school (Casad, Hale & Wachs, 2015; Soni & Kumari, 2017). To our knowledge, this is the first study that has examined the impact of parental attitudes on college-aged students' math anxiety.

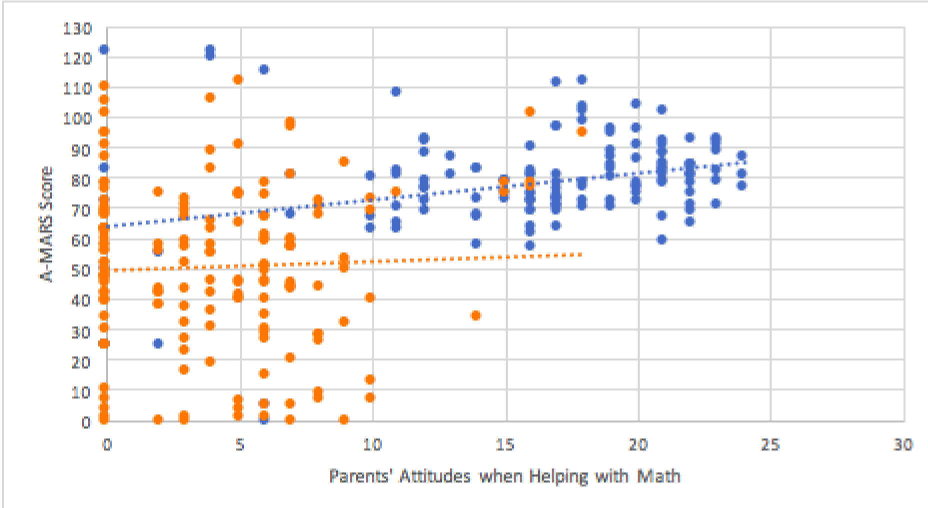


Figure 7. A-MARS Scores by Parents' Attitudes Towards Math. Parental attitudes significantly predicted students' scores on A-MARS ($\beta = 0.61$, $p = 0.02$).

Next, we examined if the likelihood that a student would major (or minor) in STEM was related to their age, hearing status, school environment, parental attitudes towards math and parental involvement in STEM careers. We hypothesized that all variables except for age would be predictors of students majoring in STEM. A student majoring in STEM ("Yes" versus "No") was a binary outcome variable, so we examined this question with a mixed effects logistic regression (see Figure 9). We coded any student with at least one plan of study (regardless of whether it was a major or minor) in STEM as "Yes".

	Estimate	Standard Error	Odds Ratio	p-value
Intercept	-3.56	2.46	0.028	0.15
Age	0.22	0.11	1.25	**0.037***
Hearing Status (Hearing)	-0.80	0.55	0.45	0.14
School Environment	0.00	0.022	1.00	0.92
Parental Attitudes	-0.03	0.033	0.97	0.39
Parent STEM	0.90	0.31	2.46	**0.0039****

Figure 8. Results from mixed effects logistic regression with student STEM major/minor (Yes or No) as the outcome variable ($p < 0.05$ *, $p < 0.01$ **, $p < 0.001$ ***).

The only significant factors in predicting whether students majored in STEM were student age and having at least one parent in a STEM career. With regards to age, older students were 1.25 times more likely to either major or minor in a STEM field ($p = 0.04$, Figure 8). This finding did not match our hypothesis, but is consistent with prior literature. For example, Robinson in 1998 found that older students (older than 28 years) were more scientifically literate than their younger counterparts (younger than 28). If scientific literacy does in fact increase with age, it would make sense for more older students to major in STEM.

Students with at least one parent in the STEM workforce were 2.46 times more likely to major in STEM themselves ($p = 0.004$), consistent with our original hypothesis. The impact parents have on their childrens' future career choices has been studied extensively, and the general consensus is that parents have at least some influence (Ing, 2014). Scientists often cite their parents as influencing them to pursue STEM (Sonnert, 2009). Parents with careers in STEM may unintentionally (or intentionally) reward their children more for succeeding in STEM courses as compared to other courses. Just as students feel more motivated to succeed in math if their instructors are enthusiastic in the classroom (Jackson & Leffingwell, 1999), children also likely internalize their parents feelings about their careers.

Inconsistent with our hypothesis, hearing status did not significantly predict whether students would major in STEM ($p = 0.14$). Eighty-two out of 162 hearing students (50.6 %) had at least one major or minor in STEM. On the other hand, 96 out of 136 deaf students (70.6%) had at least one major or minor in STEM. In spite of reporting higher average math anxiety scores, deaf students were more likely to major in STEM than hearing students. Gallaudet University found that despite DHH underrepresentation in STEM fields, the rate of STEM majors among DHH undergraduates is comparable to the rate of the general population: 17.0% of DHH undergraduates major in STEM, which is just slightly under the 18.2% rate of the general population. However, Gallaudet notes a substantial loss of DHH students between undergraduate and postgraduate school years (Solomon, Braun, Kushalnagar, Ladner, Lundberg, Painter & Nuzzo, 2012), which may be another reason we see fewer DHH individuals in the STEM workforce.

School environment also did not significantly predict students majoring in STEM ($p = 0.92$). This finding was inconsistent with our hypothesis. A potential explanation for this may be that factors besides school environment play a larger role in deciding which major to pursue in college. Prior research has found that expected earnings and perception of ability to complete coursework are some of the primary determinants of selecting a major in college (Wiswall & Zafar, 2015).

Parental attitudes towards math were not strong predictors either ($p = 0.39$, Figures 8 and 9), which was inconsistent with our hypothesis. We may need to look at other variables in parental attitudes to see an effect. For example, the importance parents gave to STEM (e.g. how important achievement in math was, how often they helped with math homework, etc.) may be a stronger predictor of students majoring in STEM. Also, parental attitudes towards math were calculated with the assumption that parents were helping their children with homework. It is worth nothing, however, that students often do not ask parents for help on their homework in college and turn to professors or resources on campus instead. Our findings support this idea because 162 (54.4%) students responded with either “Not applicable” or “Prefer not to answer” for all three questions that we used to calculate parental attitudes towards math. The first question asked how stressed parents were when helping with math, the second asked how often parents raised their voice in anger and the third asked how frustrated parents became as time went on. One hundred seventy-two students (57.7%) reported “Not applicable” or “Prefer not to answer” to the first question, 167 (56.0%) to the second and 175 (58.7%) to the third. Therefore, over half the students in our study may not have received any help from parents on their math homework.

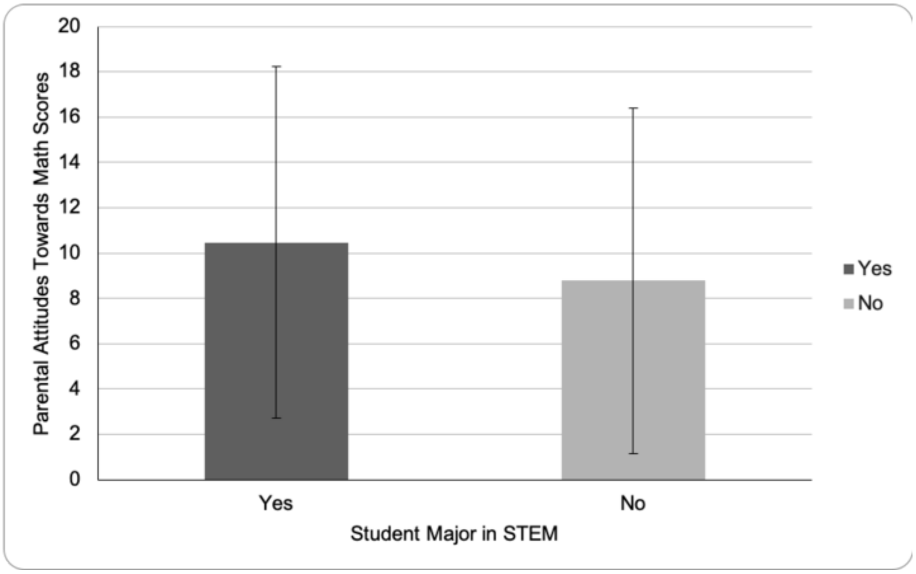


Figure 9. Parents' Attitudes Towards Math by Student Major in STEM. Parental attitudes did not significantly predict whether students would major in STEM (*p* = 0.39). Students majoring in STEM ("Yes") reported average parental scores of 10.5 (*SD*=7.77). Students not majoring in STEM ("No") reported a lower average of parental scores (*M*= 8.78, *SD*= 7.62).

Conclusion

The current study first asked if age, hearing status, school environment and parental attitudes towards math predict students' math anxiety and found that all four variables were significant predictors of math anxiety. Older students and hearing students were less math-anxious than younger and DHH students respectively. Students who reported that their universities were supportive of STEM were more math-anxious. Students who reported that their parents had negative attitudes towards math also were more math-anxious.

The second question this study asked was whether age, hearing status, school environment, parental attitudes towards math and parental involvement in STEM careers affected the probability of a student majoring in STEM. Students' ages and parents' involvement in STEM careers were strong predictors of whether they would major in STEM. Older students and students with one or more parents working in STEM fields were much more likely to major in STEM fields themselves. Hearing status, school environment and parental attitudes towards math, however, were not strong predictors of this specific outcome variable.

Age was found to be significantly predictive of both math anxiety and majoring in STEM. One of the future directions of this project would be to include the remaining demographic factors such as race, ethnicity and gender in the analyses. It is worth noting that deaf students were overwhelmingly white (91.2%) and male (64.7%). Additionally, the average SES score of the entire population was fairly high (M=46.1, SD=12.5). A future goal of this study would be to continue collecting data and encourage participation of underrepresented groups with regards to race (e.g. Native American), ethnicity (e.g. Hispanic or Latino) and gender (e.g. non-binary). We would also aim to include people from lower-SES backgrounds.

Another relationship we hope to explore is how the language experiences of DHH students affect their levels of math anxiety. In the United States alone, 90-95% of deaf children are born to hearing parents. Most of these parents have little to no exposure to American Sign Language (ASL), which is the most accessible language for their children. There are many reasons parents refuse to become fluent in ASL, ranging from embarrassment to the belief that their children must learn spoken English eventually. Even more puzzling is that parents who have been learning ASL for years often stop using it (Weaver & Starner, 2011). Additionally, the study by Ariapooran (2017) was limited in that it did not evaluate the languages DHH students used in their classrooms to communicate with one another, potentially leading to different results. This study assessed the languages used in school and at home extensively and hopes to determine the importance of language in the development of and eventual success in math. A subset of the questions we posed examined if DHH students (particularly those of hearing parents) were exposed to the languages they prefer. We hypothesize that DHH individuals who couldn't communicate in the languages they prefer at home or school will have higher levels of math anxiety, hinting at the importance of language development for math development.

Another component of our dataset that we will analyze in the future is a comparison of responses throughout the questionnaire over the two timeframes (see Figure 5). We hope to compare students' experiences growing up with their parents and at school compared to their current experiences with their parents and at university. For instance, math anxiety has been shown to be persistent in life (Maloney & Beilock, 2012); as such we hypothesize that students who report low math anxiety in middle school and high school will also have lower A-MARS scores at university, and vice versa. This study also hopes to validate findings from previous studies about the pervasiveness and persistence of math anxiety. Math anxiety is most often studied in children, so we endeavor to establish that math anxiety can continue on well into adulthood. We hypothesize that the parental attitudes' towards math will be fairly consistent across time. We also would like to see if students who changed their career aspirations from STEM to non-STEM (and vice versa) show increased (or decreased) math anxiety levels.

Math anxiety limits students' full potential in school and curbs their career opportunities. Math anxiety can be alleviated, and one of the key ways to do so is by understanding what leads it to develop in the first place so as to prevent it (Beilock & Maloney, 2012). DHH students pursue STEM plans of study in college at the same (if not greater) rate as their hearing counterparts but still report much more math anxiety and are vastly underrepresented in the STEM workforce. Understanding why this is will be key to ensuring that DHH individuals are afforded the same opportunities as hearing students.

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Having experienced math and general test anxiety for most of my academic career, this work is incredibly important to me. As someone who is not a part of the Deaf community, I am grateful to have been able to carry out this project. Thank you!

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