Title
How Do Predictors of Math Anxiety Differ?

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Publication Date
2019

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA

Los Angeles

How Do Predictors of Math Anxiety Differ?

A thesis submitted in partial satisfaction of the

requirements for the degree Master of Arts

in Education

by

Isabella Boyadjian

2019

ABSTRACT OF THE THESIS

How Do Predictors of Math Anxiety Differ?

by

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Master of Arts in Education

University of California, Los Angeles, 2019

Professor Jennie Katherine Grammer, Chair

Math Anxiety is a complex problem that can negatively impact math performance, math interest, and career choice. However, it is not clear how these factors differ from one another. Building on previous research, in this study, self-efficacy, test anxiety, and spatial working memory were examined as predictors of math anxiety. It was hypothesized that spatial working memory would be the most related trait of math anxiety. Results indicated that test anxiety was the most related to math anxiety and spatial working memory was the least associated even when accounting for gender. Despite the results contradicting the hypothesis, this study contributes to the understanding of math anxiety by showing how these traits differ and by further clarifying the link between math and test anxiety.

Keywords: math anxiety, test anxiety, spatial ability, self-efficacy, differ

The thesis of Isabella Boyadjian is approved.

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2019

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How Do Predictors of Math Anxiety Differ?

It is estimated that 17% of the U.S. population has high math anxiety (Ashcraft & Moore, 2009). Math anxiety is a negative emotional or physiological reaction towards math problems, math tests, or thinking about math courses (Ashcraft & Krause, 2007; Suinn & Winston, 2003; Richardson & Suinn, 1972). Along with negative individual feelings towards math, math anxiety is related to decreases in math performance which can impact educational outcomes and future career choices (Ashcraft & Kirk, 2001). Because science, technology, engineering and math (STEM) based school courses and careers rely on mathematics, it is crucial to understand math anxiety as it may deter students from pursuing these types of courses and careers.

A number of factors are thought to contribute to math anxiety. Predictors of math anxiety are biological, social, and environmental. Contributing factors to math anxiety include age, gender, genetics, cultural attitudes, and cognitive ability (Dowker, Sarkar, & Looi, 2016). Of these factors, self-efficacy, working memory, and test anxiety are most commonly studied. **S**elf-efficacy, first coined by Albert Bandura (1986) is the belief an individual has regarding their own ability to succeed in any given task or goal. Self-efficacy is a predictor of academic performance and determines how well a student perceives their own progress (Pajares & Kranzler, 1995). Thus, self-efficacy is important for mathematical learning because individuals must be able to monitor their performance and persist through learning a challenging subject. While self-efficacy may not be the direct cause of high or low math performance, it is essential to understand how self-efficacy relates to math performance. Higher self-efficacy could lead to more interest, persistence, and attention when an individual is faced with a challenging math problem or is having difficulty understanding math in general (Pajares & Kranzler, 1995).

Working memory is the ability to temporarily hold information while completing a task and is negatively affected by math anxiety (Baddeley & Hitch, 1974; Uttal et al., 2013). Demanding math tasks can lead to math anxiety and result in negative thoughts and emotions that consume working memory resources and direct attention away from the math problems being solved (Hembree, 1990; Ashcraft & Krause, 2001). Spatial working memory is a type of working memory and a type of spatial ability that will be the focus of this study because it is predictive of an individual's math ability and their likelihood to pursue careers in STEM. To gain a holistic understanding of math anxiety, it is important to understand how spatial working memory varies in its prediction to math anxiety when compared to other factors like test anxiety and self-efficacy.

Another contributor to math anxiety is test anxiety. Test anxiety is the worry students experience when taking standardized tests or course assessments. Although the relationship between test anxiety and math anxiety remains unclear, test anxiety negatively impacts student math performance. Several studies have shown moderate correlations between test anxiety and math anxiety but have failed to thoroughly describe the ways in which test anxiety predicts math anxiety (Liew, Lench, Kao, Yeh, & Kwok, 2014; Dowker et al., 2016; Hembree, 1990; Dew, Galassi, & Galassi, 1984). The relationship between test anxiety and math anxiety is not clearly understood and this study will further clarify the relations between test anxiety and math anxiety by accounting for other predictors of math anxiety.

In the literature review that follows, the significance of spatial abilities on mathematical thinking, specifically of spatial working memory and its relation to math anxiety will be discussed. Then, the role of self-efficacy and its relationship to math anxiety will be explained.

Finally, the relationship between test anxiety and math anxiety and how they are similar and different from one another will be further addressed.

Spatial Working Memory

Working memory is the temporary storage and manipulation of information and includes spatial working memory (Baddeley & Hitch, 1974). Spatial working memory, a type of working memory, is the ability to temporarily hold spatial information, manipulate, and transform objects in space. Spatial abilities like spatial working memory are a central component of mathematical thinking because mathematical thinking relies on visualizing numbers on a number line, creating and interpreting graphs, and manipulating shapes and equations (Reuhkala, 2001). Even basic arithmetic such as addition and subtraction rely on spatial working memory (Geary & Widaman, 1992). Individuals with higher spatial working memory are more likely to choose careers in STEM (Tosto et al., 2014; Young, Levine, & Mix, 2018).

Tosto and colleagues (2014) examined strategies for improving math interventions and math education for students with lower spatial abilities. Given research supporting the association of spatial and mathematical abilities, Tosto and colleagues wanted to further research this idea by approaching their research from a genetic perspective to understand shared and non-shared environmental components of spatial ability and its association to math ability. To examine this question, they used data drawn from a sample of 1539 dizygotic and monozygotic twin pairs of opposite gender. Participants' math and spatial ability were assessed. The results from this study indicated that the associations of math ability and spatial ability are linked with genetics (60 %), while 26% was attributed to the environment, and 14% reflected the contributions of the non-shared environment. Furthermore, the study provides more evidence of the heritability of spatial ability and that spatial abilities account for mathematical ability. The results from this study also showed the significance of spatial training for individuals with lower math ability and these results could be applicable to math anxious individuals. Because spatial abilities may not be a fixed trait it is possible to help individuals with low spatial skills improve (Tosto et al., 2014; Uttal et al., 2013).

To further understand if lower spatial ability is a risk factor for individuals with math anxiety, Georges, Hoffmann, and Schiltz (2016) conducted a study to investigate if math anxiety depends on number space associations. Participants were assessed on a variety of measures including math anxiety, number space associations, numerical distance effect, spatial ability, visuospatial working memory, inhibitory control, and processing speed. The results from this study supported the hypothesis that individuals with high math anxiety tend to have lower numerical skills. Because individuals with lower numerical skills have a difficult time understanding abstract numerical concepts, they rely on physical spatial information that is readily available for them to see (Georges et al., 2016). This study provides further evidence to show that individuals with low spatial ability could have more difficulty understanding math concepts and this might lead to the onset of math anxiety.

Passolungh and Mammarella (2012) investigated visual and spatial working memory in children with math learning disabilities and lower problem-solving skills. It was hypothesized that children with math learning disabilities would perform low on spatial working memory and visual tasks. In comparison to children without learning disabilities, children with math learning disabilities performed lower on spatial working memory tasks but not visual tasks. These findings are of interest not only because they provide further evidence to support the relationship between spatial working memory and math, but it shows that there might be a distinction between spatial and visual cognition for math learning.

Although there is a misconception that spatial abilities are a fixed trait, it is possible to help individuals improve their spatial abilities (e.g., Tosto et al., 2014). Casey et al. (2008) conducted a study testing two types of spatial interventions involving the use of block building and the use of storytelling when teaching math problems. In the story telling intervention teachers told the children that they were helping a character build a wall around a castle to prevent animals from jumping inside. The purpose of the story was to help children think about how the different blocks should be assembled. In the block building intervention, children were not given a story and had to rely on their spatial thinking to understand how different objects relate to one another and how the parts of a whole are assembled to create the walls of a castle. In the control condition, children were given a block training exercise but it was unstructured and they did not receive formal instruction. The block building exercise improved the children's spatial abilities. Storytelling was also important for children to understand how objects relate to form a whole.

There is evidence to show that mathematical thinking relies heavily on spatial ability. However, there is no clear distinction as to which type of spatial ability is important for math or if different types of math, such as algebra or geometry rely on different types spatial abilities (Rohde & Thompson, 2007). Along with individual differences of spatial ability that contribute to math anxiety and math performance, math anxiety can interfere with an individual's spatial working memory capacity. The processing efficiency theory suggests that when an individual is worried while completing a task, the worry negatively impacts their performance because it interferes with their working memory (Eysenck & Calvo, 1992). In line with the processing efficiency theory, Ashcraft and Kirk (2001) conducted a study to investigate how math anxiety interferes with working memory when an individual completes a math problem. The findings from this study showed that when learning a math task that heavily relies on working memory, individuals with math anxiety use some of their working memory resources to attend to the anxiety that they are feeling. Ashcraft and Kirk (2001) also wanted to determine the difference in working memory load by comparing learning math to doing math. To assess this, participants completed a letter transformation task and a number transformation task. The results from this study showed that individuals with higher math anxiety were slower at the transformation tasks and were also less likely to correctly recall the transformations. Furthermore, this study provided more evidence to understand how individuals with higher anxiety use more working memory resources than individuals with lower anxiety (Ashcraft & Kirk, 2001). The results from this study also show that speed and accuracy were lower for those with math anxiety, which supports the notion that it is the math anxiety and not math competence leading to a decrease in math performance.

Prior research has demonstrated the importance of spatial ability and working memory to math performance and shown evidence to support the relationship between working memory and math anxiety. However, there has been little work examining the link between spatial ability and math anxiety. It could be that math anxious individuals experience math anxiety because they have low spatial ability. The current research hopes to bridge this gap and further understand the relationship between spatial working memory and math anxiety.

Self-Efficacy

Self-efficacy is the belief an individual has regarding their own ability to succeed in any given task or goal. It is a significant predictor of math performance because individuals must be able to monitor their own progress while learning to persist through their challenges (Albert Bandura, 1986; Pajares & Kranzler, 1995). For example, if a student is not able to reflect on how they have grown and developed in a challenging math course they may not feel that they have a sense of control over their own improvement and could continue to underperform. Self-efficacy is also domain specific and having low self-efficacy in one domain, such as writing, does not mean that an individual will have low self-efficacy in another domain, like math or science (Lent, Brown, & Gore, 1997). The impact of self-efficacy on math performance is especially important to math anxiety because if math anxious individuals cannot monitor their own growth and development through a difficult math course, they will potentially face greater underperformance compared to non-math anxious individuals.

Lent et al. (1997) examined the extent to which math self-efficacy predicted math-based career choice and expected performance. They also examined whether academic self-concept would be a better predictor of overall grades instead of specific performance in a subject. Participants completed measures of self-efficacy for mathematics, self-concept, and occupational goals. Academic ability measures were also assessed. Findings from this study showed that math self-efficacy is different from general self-concept measures. Having higher self-efficacy that is domain specific to math is predictive of performance and choosing math related courses or careers.

Self-efficacy is predictive of math anxiety. However, math anxiety could depend on the complexity of the math problem and how efficiently the problem can be solved. Hoffman (2010) wanted to determine how low math anxiety and low self-efficacy relate to problem solving efficiency. Participants completed the Abbreviated Math Anxiety Scale (AMAS), working memory tasks, and self-efficacy measures. The researchers also controlled for gender and working memory because they were only interested in how self-efficacy and problem-solving efficiency predicts math anxiety. Participants were asked to mentally solve multiplication problems and the number of digits increased to make the problems more complex.

When presented with easy problems, Hoffman (2010) found that self-efficacy increased and math anxiety decreased. However, when the complexity of the problem increased, math anxiety increased and self-efficacy decreased. Individuals with high self-efficacy were more accurate when solving problems regardless of the difficulty of the problem. Findings from this study provide further insight to the role self-efficacy plays in math anxious individuals. The study also provides support for processing efficiency theory (Eysenck & Calvo, 1992). The findings showed that anxiety impairs individual performance when the individual feels that they cannot complete the math problems or when the problem difficulty increased (Hoffman, 2010). Self-efficacy mediates math ability and math anxiety scores. Individuals who exhibit low self-efficacy tend to have higher math anxiety compared to those with low math anxiety. Because there is substantial evidence to show that self-efficacy is a significant predictor of academic and math ability, it is important to further explore self-efficacy and how it differentiates from other predictors of math anxiety.

Test Anxiety

Students experience test anxiety when they are taking standardized assessments or assessments in any academic domain. Though moderate levels of test anxiety can serve as a motivator when taking a test, too much anxiety interferes with performance. Like math anxiety, test anxiety leads to underperformance and can put students behind if it is severe enough to interfere with their academic work (Liew et al., 2014). Test anxiety is not entirely separate from math anxiety, but math anxiety and test anxiety still differ in some ways (Dowker et al., 2016). It is challenging to fully understand the role of test anxiety within math anxiety because no current studies have looked at the differences between test anxiety in math courses and test anxiety in other courses, like English, history, or science.

Two factors involved with test anxiety are worry and emotionality (Libert & Morris, 1967). Whereas worry is central to cognitive thoughts related to concerns about one's success, emotionality aligns more with actual feelings of anxiety and the components of anxiety that come with it. Liew et al. (2014) conducted a study to explore how avoidance temperament interferes with testing, which predicts low math performance on standardized tests and classroom tests. To assess avoidance temperament and evaluation of threat, participants completed self-report measures that asked how easily they become upset and nervous, how threatened they feel by the test, and if they feel that they will not perform well. Math performance was assessed by participants completing the reasoning portion of the SAT. To assess performance of in-class tests, participants reported the grades they received for their math classes. Findings from this study support the hypothesis that an avoidance temperament is related to perceived threat. Individuals with higher self-report scores on temperament and avoidance temperament had lower scores on the standardized math assessment. However, in relation to their self-reported grades from their math courses, results showed that they were only related to the way the participants evaluated threat (Liew et al., 2014). The results from this study also showed that standardized test performance is mediated by temperament avoidance. It is much more difficult for anxious individuals (test or math anxious) to focus on completing a task when their thoughts are concentrated on negative outcomes. Implications from this study are important for developing a better understanding of the relationship between math and test anxiety to develop interventions that target the specificities of anxiety.

Similar to math anxiety, it is hypothesized that test anxiety drains resources needed to perform which results in decreased performance (Hembree, 1990). Dew et al. (1984) tested the relationship between math and test anxiety by using self-report measures. An interesting finding is that test anxiety and math anxiety were not highly correlated with one another indicating that although test anxiety and math anxiety are related, they are still separate from one another.

To investigate the differences between math anxiety and test anxiety, Kazelskis et al. (2000) conducted a study where participants completed questionnaires to measure test and math anxiety and questionnaires asking about various dimensions of emotionality and worry. Participants completed the Suinn Test Anxiety Behavior Scale (STABS), which simulates a test environment to induce anxiety in individuals who have test anxiety. Across all measures, Kazelskis et al. (2000) found moderate correlations except for correlations between the math anxiety measures which had correlations above 0.60. Differences between math anxiety and test anxiety measures were similar for both males and females. Findings from Kazelskis et al. (2000) study did not provide evidence for any major differences between math anxiety and test anxiety. However, the researchers noted that because the math anxiety measures in the study correlated with one another, there may have been differences within the math anxiety measures that contributed to the lack of findings in the study. Kazelskis et al. (2000) study also shows that the measures used for math and test anxiety may differ depending on the type of study so it is possible that these measures may not thoroughly explain the similarities and differences between test and math anxiety in other experiments or educational contexts.

Though there seems to be a fine line between math and test anxiety, math anxiety is specific to numbers or problems involving computations whereas test anxiety can be observed in various contexts. Zettle and Raines (2000) found that test anxiety was more closely related to math anxiety than trait anxiety. However, the relationship between test and math anxiety was insignificant and differed depending upon gender. Although the results from this study did not provide clear insight into the link between math anxiety and test anxiety, the findings provided further background information to understand what may be occurring in math and test anxious individuals.

Direct relationships between test anxiety and math anxiety are still lacking in the literature. It is important to understand how test anxiety predicts math anxiety to develop effective treatments. If it is not simply the math test but the math anxiety that is leading to decreased performance then better interventions can be implemented. This study will further explore the role of test anxiety in relation to math anxiety by determining how test anxiety predicts math anxiety when compared to self-efficacy and math anxiety.

Current Study

Interventions to increase self-efficacy or interventions to reduce test and math anxiety alone may not be enough to improve performance in math anxious individuals. To improve the effectiveness of math anxiety interventions, it is important to understand how the behavioral and cognitive factors that contribute to math anxiety vary in their relation to math anxiety. Despite the demonstrated relationships between math anxiety and self-efficacy, spatial working memory, and test anxiety, few studies have looked at how these behavioral and cognitive factors differentiate in their relationships to math anxiety. By comparing the relationships between predictors of math anxiety, better interventions could be developed.

The purposes of this study are to 1) determine how self-efficacy, spatial working memory, and test anxiety relate to math anxiety and determine how these factors differentiate in their relationship to math anxiety, and 2) further investigate the relationship between test anxiety and math anxiety by comparing test anxiety to other predictors of math anxiety. To achieve this goal, a multiple linear regression analysis will be used to determine how these traits differentiate in their relationship to math anxiety and to further explore the relationship between test anxiety and math anxiety.

RQ1: How do test anxiety, spatial working memory, and self-efficacy differ in their relationship to math anxiety?

Hypothesis 1: Previous research has found the above traits to be related to math anxiety but it is unknown how these traits differentiate in their relationship to math anxiety. In other words, although all these traits are related to math anxiety, which one is the most related? Of these factors, it is expected that spatial working memory will be the most related trait of math anxiety because spatial abilities are predictive of individuals pursuing courses and careers in STEM.

RQ2: Is test anxiety uniquely predictive of math anxiety when accounting for self-efficacy and spatial working memory?

Hypothesis 2: Previous research has found that test anxiety and math anxiety are moderately related but the literature has yet to clarify this relationship. It is expected that test anxiety will be moderately related to math anxiety but it will not be the most predictive of math anxiety when accounting for spatial working memory and self-efficacy.

Method

Participants

The data subset is from a secondary data set that consisted of 350 undergraduate students from the University of Michigan (210 females, 138 males) with a mean age of 19.77 years, age range 18-57, *SD* = 7.07 who participated in the study for course credit or for $20. Thirty-six participants were excluded from the data analysis because they did not complete all measures.

Materials

Participants completed three individual difference measures: The Abbreviated Math Anxiety Scale (AMAS), Motivated Strategies for Learning Questionnaire (MSLQ), and the Automated Symmetry Span Task (SSPAN) to measure spatial working memory.

Math Anxiety. The Abbreviated Mathematics Anxiety Scale (AMAS) (Hopko et al., 2003) is a nine-item math anxiety questionnaire adapted from the 98 item Mathematics Anxiety Scale by Richardson & Suinn (1972). The AMAS consists of self-report measures with responses ranging from 1 (*not anxious at all*) to 5 (*very much anxious*) when asked how anxious they feel in a math-based context with possible scores ranging from 9-45.

Cognitive Measures. To measure participants' test anxiety and self-efficacy, the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich & DeGreto, 1990) was used. Each item on the questionnaire was measured on a scale ranging from 1 (*not at all true of me*) to 7 (*very true of me*). There were nine items measuring self-efficacy with possible scores ranging from 9-63. These items consisted of questions such as, "*compared to other students in this class I expect to do well*" and "*I am certain that I can understand the ideas taught in this course."* The four items measuring test anxiety had possible scores ranging from 4-28 and consisted of questions such as, *"I am so nervous during a test that I cannot remember facts I have learned*" or "*I worry a great deal about tests*."

Spatial Working Memory. To assess spatial working memory, a computerized Symmetry Span Task (SSPAN) was used (Redick et al., 2012). The SSPAN task measures spatial working memory by having participants memorize the position of colored squares on a matrix. The squares within the matrix light up with the color red and participants then click on the square that lit up in a specific order. The symmetry part of the task is where participants judge whether or not a picture is symmetrical. If the picture can be folded in half vertically and the picture on the left lines up with the pictures on the right, then that means the picture is symmetrical. The task alternates between deciding about the symmetry of picture and asking participants to make a decision about the picture of a square appears on the screen. The task could take up to 15 minutes to complete but time varied by participant.

Procedure

After participants read and signed the consent form, they were presented with all measures on the computer on Qualtrics platform. Participants completed the cognitive and math anxiety questionnaire on Qualtrics. Then, participants completed the working memory task and were then debriefed and thanked for their participation.

Results

Plan of Analyses

To examine how spatial working memory, self-efficacy, and test anxiety differentiate in their relationship to math anxiety, data were first explored using descriptive statistics and correlations. Following the exploration of data, a multiple linear regression model was used to determine how these variables differ in their relationship to math anxiety and which variable would be the most predictive of math anxiety. An exploratory multiple regression analysis with gender as a variable was also conducted.

Descriptive Analysis

Table 1 shows the mean scores, range, standard deviations, skewness, and kurtosis for self-efficacy, test anxiety, spatial working memory, and math anxiety. None of the data were skewed as indicated by skewness statistics which fell within the range of -1 to 1 and were close to 0.

Correlation Analysis

Table 2 shows the bivariate correlations of spatial working memory, test anxiety, and self-efficacy to math anxiety. Spatial working memory was significantly related to math anxiety. As can be seen in Figure 1, lower scores of self- efficacy were related to higher scores of math anxiety, $r(312) = -0.47$ $p < 0.01$. Figure 2 shows that higher spatial working memory was related to lower math anxiety, $r(312) = -0.19$, $p < 0.01$. Test anxiety was significantly related to math anxiety such that, higher scores of test anxiety were related to higher scores of math anxiety (figure 3), $r(312) = 0.57$, $p < 0.01$.

Multiple Linear Regression Analysis

To determine how self-efficacy, test anxiety, and spatial working memory differentiate in their relationships to math anxiety, a multiple linear regression was conducted (for full results, see table 3). Regression assumptions of normality and linearity were checked and met. The full model significantly predicted math anxiety, $F(3, 313) = 61.7$, $p < 0.01$, $r^2 = 0.37$ accounting for 37% of the variance of math anxiety. Test Anxiety ($\beta = 0.43$, $p < 0.01$), self-efficacy ($\beta = -0.23$, $p < 0.01$) , and spatial working memory ($\beta = -0.13$, $p < 0.01$) were all significant predictors of math anxiety.

Regression analysis revealed spatial working memory to be the least related to math anxiety when compared to all other measures. An increase of one standard deviation in spatial working memory is associated with a decrease of 0.13 standard deviations in math anxiety. Consistent with previous literature, test anxiety remains to be moderately related to test anxiety. Contrary to the hypothesis, test anxiety was the most related trait of math anxiety with an increase in test anxiety relating to an increase of 0.43 standard deviations in math anxiety when controlling for self-efficacy and spatial working memory.

To determine if the addition of gender would change the model fit, a separate multiple regression analysis including gender was conducted. The full model significantly predicted math anxiety, $F(4, 313) = 48.72$, $p < 0.01$, $r^2 = 0.39$, accounting for 39% of the variance of math anxiety. Test anxiety ($\beta = 0.41$, $p < 0.01$), self-efficacy ($\beta = -0.23$, $p < .01$), spatial working memory ($\beta = -0.10$, $p < 0.01$), and gender ($B = 1.66$, $p < 0.01$) were all significant predictors of math anxiety. Gender was one of the least predictive variables of math anxiety. Table 4 shows the results from the analysis with gender.

Discussion

This study expands math anxiety research by further understanding known predictors of math anxiety and how they differentiate from one another. The math anxiety predictors of interest were spatial working memory, self-efficacy, and test anxiety. Spatial working memory, test anxiety, and self-efficacy were significantly related to math anxiety. However, of these predictors, only test anxiety and self-efficacy were moderately related to math anxiety. Test anxiety was positively related to math anxiety so an increase or decrease of test anxiety is likely to change the relationship to math anxiety. Similarly, increases or decreases of self-efficacy are also more likely to change the relationship to math anxiety. Spatial working memory was predictive of math anxiety but weakly related. It is likely that increases or decreases of spatial working memory will not change the likelihood of the relationship between spatial working memory and math anxiety. Therefore, individuals could have math anxiety regardless of high or low spatial working memory.

It was hypothesized that spatial working memory would be the most predictive of math anxiety because spatial ability is an important cognitive process for math (Young et al., 2018). However, test anxiety was found to be the most predictive of math anxiety while spatial working memory was the least predictive of math anxiety even when accounting for gender. While spatial working memory is related to math anxiety and accounts for success in math and science, when accounting for other cognitive and behavioral processes, the results showed that it did not influence math anxiety like test anxiety and self-efficacy. Different types of math (e.g., geometry) may rely on different types of spatial abilities (e.g., spatial orientation) (Rohde & Thompson, 2007; Young et al., 2018). Despite the results of this study not showing spatial working memory to be the most predictive of math anxiety, it does not mean that other forms of spatial abilities in different math contexts will not be predictive of math anxiety. Previous theories of math anxiety have posited that math anxiety overloads working memory making it difficult for individuals to process mathematical information (Ashcraft & Krause, 2001). A possible explanation for this finding is that spatial working memory might not be the spatial ability that math greatly relies on (Passolungh & Mammarella, 2012). Since the findings from this study showed test anxiety to be the most predictive trait of math anxiety, having low spatial ability and low test anxiety could decrease the onset of math anxiety. Future studies should clarify this phenomenon by examining math anxiety and test anxiety in individuals who have high and low spatial abilities to further clarify how spatial abilities influence math anxiety.

Despite the original hypotheses, results revealed that test anxiety, not spatial working memory was the most strongly related to math anxiety. This finding does not contradict previous literature but it is interesting that even though test anxiety is moderately related to math anxiety, it was the most related trait of math anxiety when compared to other cognitive and behavioral measures. These results provide more evidence to show that even though test anxiety and math anxiety are separate from one another, they are highly related (Kazelskis et al., 2000). A probable explanation is that regardless of one's self-efficacy or spatial ability, the worry that comes with test anxiety interferes with the ability to think which then hinders their performance (Hembree, 1990). As a result, those who have test anxiety might be more likely to be math anxious. Future studies should further clarify the link between test anxiety and math anxiety by collecting participants' general anxiety to compare it to test anxiety, math anxiety, and other behavioral and cognitive traits. Perhaps individuals with generalized anxiety or test anxiety also experience math anxiety and would benefit from more effective interventions to become comfortable with math. Future studies should also consider students' test anxiety in other courses relative to anxiety in math classes. It is important to understand if test anxiety increases or decreases depending on the type of course that a student is taking.

When accounting for math anxiety by spatial working memory, test anxiety, and self-efficacy, gender does not have as large of an impact. Indeed, gender was the least predictive of math anxiety. One explanation for this finding is that although females tend to have higher math anxiety and are less likely to choose careers in STEM (Hembree, 1990; CES, 2001), other cognitive and behavioral traits have a greater impact on deterring women from these fields. These results do not contradict previous findings because gender was found to be predictive of math anxiety. Perhaps the gender gap is not be due to the anxiety itself but it is due to environmental conditions and perceptions of math ability and math competence (Haynes et al., 2010; O'Brien & Crandall, 2002).

Self-efficacy was neither the most nor the least related to math anxiety when compared to test anxiety and spatial working memory. Participants in this sample did not have unusually high or low self-efficacy scores either. Having high self-efficacy when taking difficult courses is important for student success (Pajares & Kranzler, 1995). Without being able to monitor one's own growth and understanding, it is difficult to progress through challenging material like math. For example, an individual who does not have self-efficacy with math will experience anxiety when doing math, hearing about math, and being presented with mathematical information. As a result, the lack of efficacy could increase test anxiety and further decrease performance. In line with the findings from Hoffman (2010), math anxiety and self-efficacy might only be related when the individual encounters a difficult math problem. For example, an individual could have higher self-efficacy when solving an algebra problem but have lower self-efficacy when solving a calculus problem. Therefore, it is likely that self-efficacy is dependent on the math context and is not a general predictor to math anxiety.

Limitations

The sample was drawn from a large public university so it is not known if the average scores on all self-report measures will be consistent throughout the population. However, even though these findings might not entirely reflect the variation of math anxiety, self-efficacy, spatial working memory, and test anxiety that occurs in the general population, it is still possible to gain insight to the cognitive and behavioral differences of predictors of math anxiety that might be similar to other populations. The mean math anxiety score from this sample is consistent with the mean math anxiety score of 23.2 that Hopko et al. (2003) found when the

AMAS was developed. This consistency shows that it is likely that average math anxiety scores in the general population will be consistent if using the same math anxiety measure.

Findings did not support the hypothesis that spatial working memory would be the most predictive of math anxiety. Participants in this study did not have unusually high scores of spatial working memory so it is unlikely that this relationship was established due to the nature of the sample. However, one of the limitations of this study was that spatial working memory was the only type of spatial ability that was studied. Since it is not the only component of spatial ability that is necessary for mathematical thinking, it is possible that spatial rotation, orientation, or visualization will be more predictive of math anxiety than spatial working memory. This is an important issue for future research to address to gain a clearer understanding of the types of spatial abilities are most related to math anxiety and how different types of spatial abilities differ from other cognitive and behavioral processes, such as test anxiety and self-efficacy, in math anxious individuals.

The finding that self-efficacy was not as predictive of math anxiety may be due to the self-report questions themselves. For example, questions measuring self-efficacy asked participants how they view themselves and their performance compared to the rest of the class. The phrasing of these questions seems to capture the competitive nature of the participant instead of their own efficacy. Further development of questionnaires could be more effective if they address how the individual feels about their own learning and performance regardless of what they think about other students in the class. It is also necessary to address the differences between math self-efficacy and general self-efficacy. Lent et al. (1997) found a relationship between math anxiety and self-efficacy by using math self-efficacy specific measures instead of general questions. Future studies examining the link between self-efficacy and math anxiety should consider using math specific questions regarding self-efficacy to reconcile these differences.

Conclusions

Math anxiety is a complex phenomenon with several causes (Dowker et al., 2016; Georges et al., 2016; Lent et al., 1997). The traits that are related to math anxiety vary from individual to individual. For example, perhaps spatial ability contributes to math anxiety in one individual while test anxiety contributes to another. Findings from this study provide further insight to understanding how predictors of math anxiety differentiate in their impact on math anxiety. Future work should be conducted to further examine the link between different types of spatial ability and math anxiety as well as how math anxiety and test anxiety relate to one another. By understanding the complexity of math anxiety we can begin to develop holistic and effective interventions to help individuals become more comfortable with math.

Table 1

Descriptive statistics for self-efficacy, test anxiety, spatial working memory (SWM) and math anxiety

Measure	*N*	*Mean*	*SD*	*Range*	*Skewness*	*Kurtosis*
Self-Efficacy	314	41.18	11.51	9 - 63	-0.32	-0.52
Test Anxiety	314	15.95	6.13	4 - 28	0.09	-0.80
SWM	314	29.45	8.09	3 - 42	-0.69	-0.12
Math Anxiety	314	25.07	6.81	9 - 45	-0.25	-0.27

Table 2

Correlation Matrix Showing the Relationship Between Math Anxiety and Self-Efficacy, Test Anxiety, and Spatial Working Memory (SWM)

Measure	1	2	3	4
1. Self-Efficacy	--	--	--	--
2. Test Anxiety	-0.54*	--	--	--
3. SWM	0.08*	-0.11*	--	--
4. Math anxiety	-0.47*	0.57*	-0.19*	--

Note: *$p < 0.01$

Table 3

Multiple Linear Regression Analysis of Test Anxiety, Self-Efficacy, and Spatial Working Memory (SWM) as Predictors of Math Anxiety

Measure	*SE*	*β*	*B*	*t*	*p*
Test Anxiety	0.06	0.43	0.48	8.01	0.00
Self-Efficacy	0.03	-0.23	-0.13	4.19	0.00
SWM	0.04	-0.13	-0.11	2.89	0.004

Table 4

Multiple Linear Regression Analysis of Test Anxiety, Self-Efficacy, Spatial Working Memory (SWM) with Gender Added as an Exploratory Variable

Measure	*SE*	*β*	*B*	*t*	*p*
Test Anxiety	0.06	0.41	0.45	7.60	0.00
Self-Efficacy	0.03	-0.23	-0.13	-4.26	0.00
SWM	0.04	-0.10	-0.09	2.20	0.03
Gender	0.65	0.12	1.66	2.55	0.00

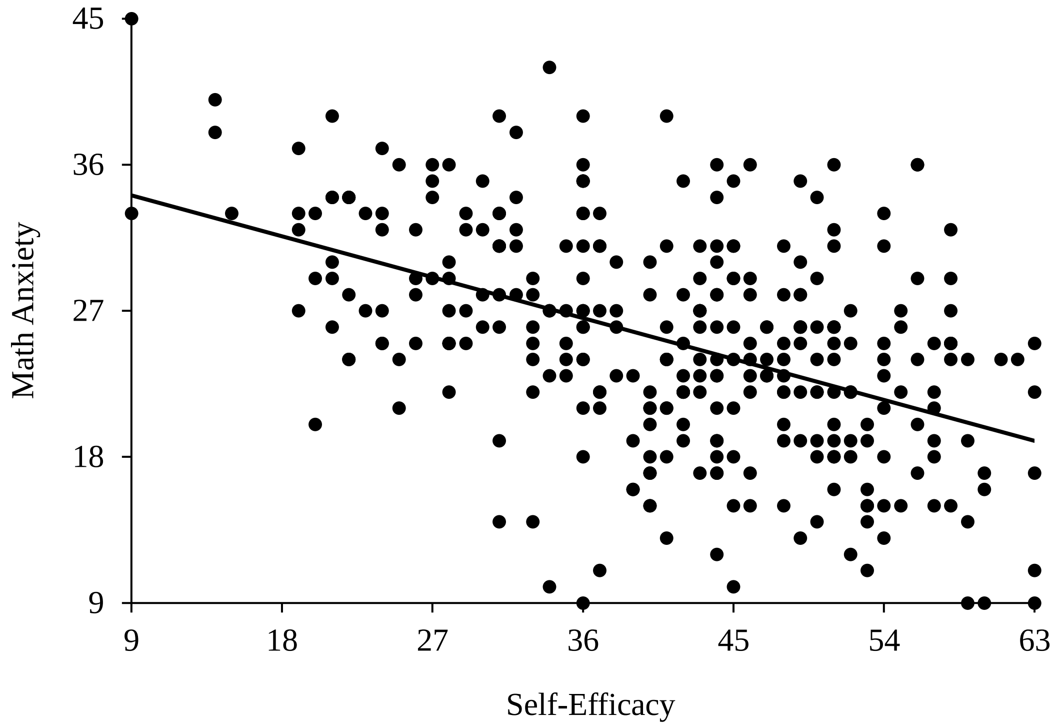

Figure 1. Higher scores of math anxiety are related to lower self-efficacy.

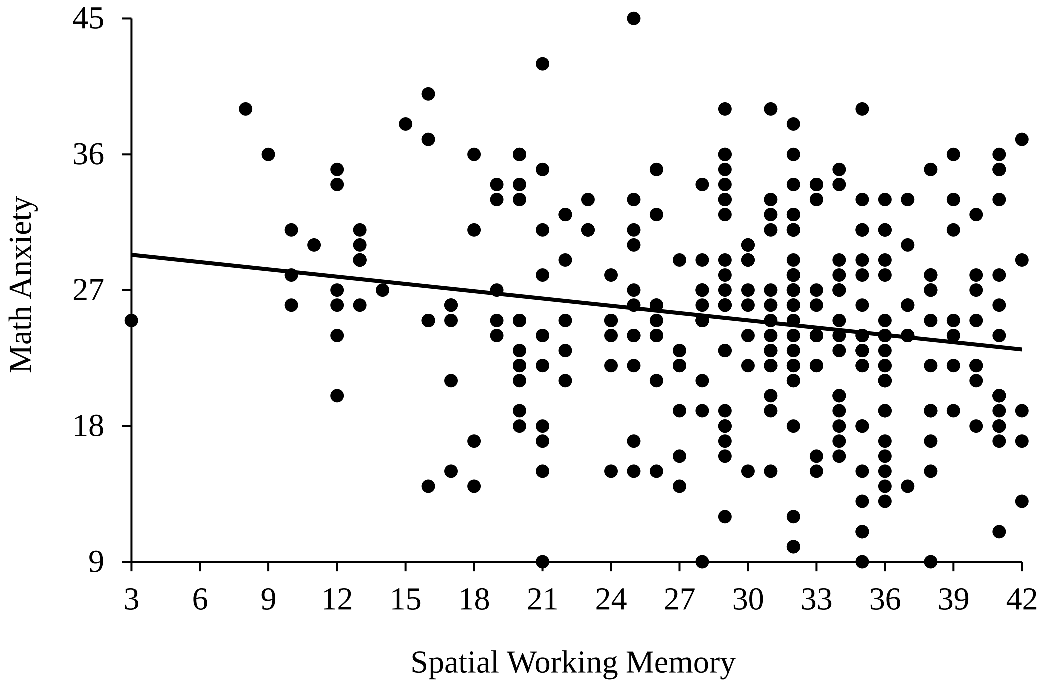

Figure 2. Higher spatial working memory is related to lower math anxiety.

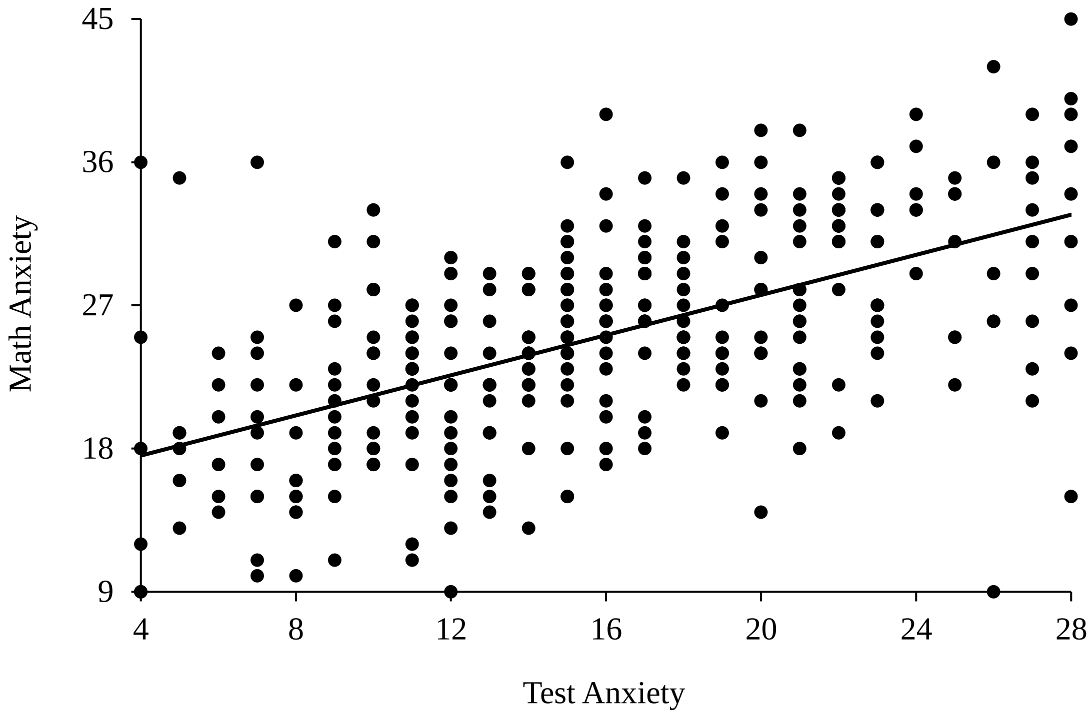

Figure 3. High math anxiety is related to higher test anxiety

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