UNDERSTANDING THE RELATIONSHIP BETWEEN MATHEMATICS ANXIETY AND MATH FACT FLUENCY IN FOURTH AND FIFTH GRADE STUDENTS

By

CHRISTINA LOUISE PYNN

Bachelor of Arts in Psychology
University of Kansas
Lawrence, Kansas
2016

Master of Science in Educational Psychology
Oklahoma State University
Stillwater, Oklahoma
2018

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July 2022

UNDERSTANDING THE RELATIONSHIP BETWEEN MATHEMATICS ANXIETY AND MATH FACT FLUENCY IN FOURTH AND FIFTH GRADE STUDENTS

Dissertation Approved:

Dr. Gary Duhon

Dissertation Adviser

Dr. Ryan Farmer

Dr. Brian Poncy

Dr. Jam Khojasteh

Name: CHRISTINA PYNN

Date of Degree: JULY 2022

Title of Study: UNDERSTANDING THE RELATIONSHIP BETWEEN MATHEMATICS ANXIETY AND MATH FACT FLUENCY IN FOURTH AND FIFTH GRADE STUDENTS

Major Field: SCHOOL PSYCHOLOGY

Abstract: This study investigated the predictive relationship between mathematics anxiety and mathematics performance using a more sensitive measure of performance, fluency. Fourth and fifth grade students completed a seven-page packed which included a demographic questionnaire, the Mathematics Anxiety Scale for Children (MASC), a mixed math probe measuring accuracy, timed tests in basic mathematical operations (i.e., addition, subtraction, multiplication, and division). Findings from the hierarchical multiple regression suggests that in addition to demographic information and accuracy-based measures, adding fluency to the model increased the overall model's predictive capacity at predicting overall mathematics anxiety. Additionally, when controlling for the impact of all other variables, fluency maintained a significant unique contribution towards mathematics anxiety. Discussion focuses on implications for school personnel providing services to support and remediate math skill development in children.

TABLE OF CONTENTS

Chapter Page

I. INTRODUCTION 1

Purpose of Proposed Study 5
Research Questions 6
Hypotheses 7

II. REVIEW OF LITERATURE 8

Mathematics in America 8
Mathematics Anxiety 10
Prevalence 11
Variables Related to Mathematics Anxiety 12
Causes of Math Anxiety 17
Instructional Hierarchy 23
Fluency Building 28

III. METHODOLOGY 40

Participants 40
Research Design 41
Measures 41
Procedures 45
Data Analysis 46

IV. RESULTS 49

Research Questions & Hypotheses 50
Descriptive Statistics 51
Assumptions 54
Regression Results 58
Summary 62

Chapter Page

V. DISCUSSION & IMPLICATIONS 64

Discussion 64
Implications 67
Limitations 68
Future Research 70
Conclusion 70

REFERENCES 72

APPENDICES 84

LIST OF TABLES

Table Page

Table 1.1. *Benchmarks for Critical Mathematical Foundations* 32
Table 2.1. *Single Skill Scope and Rationale* 42
Table 3.1. *Sample Characteristics* 51
Table 3.2. *Predictor and Outcome Descriptive Statistics* 52
Table 3.3. *Sample Characteristics Descriptive Statistics* 53
Table 4.1. *Correlation Matrix* 55
Table 4.2. *Collinearity Statistics* 56
Table 4.3. *Durbin-Watson Test* 56
Table 4.4. *Cook's Distance* 58
Table 4.5. *Blocks for Hierarchical Multiple Regression* 58
Table 4.6. *Model Summary* 59
Table 4.7. *Model Comparisons* 60
Table 4.8. *Overall Model Coefficients* 61
Table 4.9. *Summary of Tested Hypotheses* 63

LIST OF FIGURES

Figure Page

Figure 1.1. *Q-Q Plot of Residuals* 55
Figure 1.2. *Residual Plots* 57

CHAPTER I

INTRODUCTION

In education, individuals may suffer from state anxiety which is connected to a specific academic domain. The most common form of academic anxiety is mathematics anxiety (Blazer, 2011). Mathematics anxiety is commonly defined as a feeling of tension, discomfort, worry, and/or frustration during math tasks in a wide variety of ordinary and academic situations (Ashcraft & Moore, 2009; Richardson & Suinn). Students report feelings of mathematics anxiety as young as first grade and by 15 years old approximately 30% students internationally report feelings of worry, stress, and avoidant behavior in regard to mathematics tasks (PISA, 2012). The U.S. in particular has seen a decline in mathematics performance and attitudes toward mathematics (Phillips, 2009). The U.S. ranks 48 in quality of mathematics and science education, and by eighth grade the average student is not meeting proficiency benchmarks in mathematics (Wilkinson & Bevir, 2007). In elementary school, more than 20% of students are identified as at-risk and needing remediation in mathematics (Burns, et al., 2010).

The decline is also seen as student progress through the education system. Far less students meet benchmarks for mathematics proficiency in eighth grade compared to fourth grade, and by the time students are in 12^{th} grade less than 25% are considered proficient (Grigg, et al., 2007; National Mathematics Advisory Panel [NMAP], 2008). As students perform poorly on these specific academic tasks, they may be developing a negative relationship with mathematics that influences their future attitudes and avoidant behaviors towards this specific academic domain.

But why is math so important? Students who lack the confidence and skills to continue education with mathematics and science may be limited in their opportunity to be successful in an information era where “mathematics is used to represent information” (Roman, 2004, p. 16). Mathematics is integrated into most careers; with science, engineering, technology, and mathematics (STEM) occupations projected to grow 10.5% in the next 8 years, compared to 3.7% growth in all other occupations, over 75% of employers require applicants to have proficiency in algebra and geometry skills (Cabell, et al., 2021; Fayer, et al., 2017). Students who have high mathematics anxiety are more likely to avoid math related tasks, courses, college majors, and careers (Hackett, 1985; Johnston-Wilder, et al., 2014; Lyons, et al., 2012; Pizzie & Kraemer, 2017).

Despite the prevalence and negative effects, there is little consensus on the causes and maintaining variables of mathematics anxiety. The Discrepancy Theory (Tobias, 1986) purposes that awareness of previous poor performance, current performance, and student study skills may elicit mathematics anxiety. In support of The Discrepancy Theory, longitudinal research shows that prior achievement significantly predicted later performance and attitudes toward mathematics; in contrast, prior attitudes toward mathematics did not predict later performance (Ma & Xu, 2004). However, research to the contrary supports that mathematics anxiety causes poor performance (Ashcraft & Kirk, 2001; Wine, 1971). This is supported in research that demonstrates poorer performance when state specific anxiety is provoked and interferes with working memory capacity (Shi & Lui, 2016). This relationship becomes more complicated in relation to complexity of the task (e.g., simple multiplication vs algebra) (Hembree, 1990; Ma, 1999).

There is consensus that there is a small to moderate negative correlations between mathematics performance and mathematics anxiety (Hembree, 1990; Ma, 1999). However, Ma (1999) note that method of measurement may contribute to these weak correlations. Studies who use commercially developed achievement tests or percentage correct calculations gathered from teacher grades tend to find a weaker relationship between performance and mathematics anxiety (Dower, et al., 2019; Supekar, et al., 2015; Wood, et al., 2012). These measurements of knowledge heavily rely on accuracy as an indication of performance. Furthermore, in studies aiming to measure math anxiety in younger children found weak correlations between mathematics performance and mathematics anxiety (Dower, et al., 2019; Wood, et al., 2012). In these instances, students were solving basic math problems and as students age increased, along with complexity of the problem, mathematics anxiety was found to increase (Wood, et al., 2012). Using broad, accuracy-based measures of mathematics performance may not be the most appropriate measurement of students' knowledge mathematics problems (Skinner & Schock, 1995). It may also be the case that poor performance measured beyond accuracy does impact mathematics anxiety, however this may not be seen till the students solve more complex problems where a solid foundation of basic mathematics facts is needed for success.

It may be helpful to view learning as occurring in the four stages proposed by Haring and Eaton (1978) known as the "Instructional Hierarchy". The four phases include acquisition, fluency, generalization, and adaption. To achieve a more advanced stage of learning (i.e., fluency) has many benefits which include: (a) frees up working memory (NAMP, 2008; Pellegrino & Goldman, 1987; Tolar, et al., 2009); (b) increases the amount of opportunities a student has to practice the problems (Skinner, 1998); (c) increases access to reinforcement from the desired task (Martens, et al., 1992; Zaman, et al., 2010); and (d) decreases the students effort (Zaman, et al., 2010). Theoretically, if students only reach the first phase of the Instructional Hierarchy, it may create a cycle of frustration and poor performance with higher effort tasks leading to tension, worry, and math avoidance; in support of The Deficit Theory this would further increase one's level of mathematics anxiety.

Knowledge and mastery of skill in education, and mathematics anxiety research, is typically determined by accuracy-based measurements. However, more advanced stages of learning happen beyond acquisition of skill and are needed to gain mastery of a skill (Rivera & Bryant, 1992). Students need to be able to perform tasks quickly and with ease to be able to adapt and problem solve when faced with novel or more complex tasks. Cates and Rhymer (2003) sought to determine if the relationship between mathematics anxiety and performance may be better understood by using a more advanced stage of learning as measurement of performance in college-aged students. Fluency- and accuracy-based measures across five mathematics skills (i.e., addition, subtraction, multiplication, division, and linear equations) were used to determine if mathematics anxiety may be better related to fluency, and if it is more apparent when multiple operations are required. Researchers found that high levels of math anxiety were more related to fluency than to accuracy. Additionally, mathematics anxiety became more apparent as the difficulty of the task increased (i.e., addition versus linear equations) (Cates & Rhymer, 2003). This supports the notion that increases in mathematics anxiety is associated with more complex mathematics problems (Dowker, et al., 2019; Wood, et al., 2012).

Purpose of the Proposed Study

Understanding the relationship between mathematics anxiety and measures of mathematics performance has implication on how educators and school personnel treat, and more importantly prevent, the problem. If mathematics anxiety has a stronger relationship with more advanced measures of performance (i.e., fluency), then instruction and interventions that incorporate fluency practice may be two-fold by increasing performance and decreasing feelings of anxiety toward mathematics. If a history of poor performance and high effort on mathematics tasks precedes mathematics anxiety, then interventions targeting specific skill deficits may alleviate frustrations and allow students to master the content. However, if mathematics anxiety is more associated with an underlying mechanism causing student to have diminished performance, or is not related to performance at all, then interventions targeted at improving skill are likely to be ineffective in decreasing worry and avoidance of mathematics tasks.

The purpose of this study is to expand upon research examining mathematics anxiety as it is related to a more sensitive measure of performance (i.e., fluency) in fourth and fifth grade students. During this academic period, students advance from simple to more complex problem (e.g., multiplication, division, fractions). If students fail to learn basic math facts at the elementary level, they may have trouble advancing to more complex concepts and experiences higher levels of anxiety surrounding mathematics tasks. When demographic and accuracy have already been controlled for, this study aims to explore if fluency adds unique variance and aids in predicting mathematics anxiety.

Research Questions

The research questions for this study are:

Research Question 1: Is there a statistically significant relationship between demographics, math fact accuracy, and math fact fluency on math anxiety scores in fourth and fifth grade students?

Research Question 2: Is there a statistically significant contribution of demographic variables in predicting math anxiety in fourth and fifth grade students?

Research Question 3: Controlling for demographics, is there a statistically significant contribution of overall accuracy in predicting math anxiety in fourth and fifth grade students?

Research Question 4: Controlling for demographics and accuracy, is there a statistically significant contribution of overall fluency rate in predicting math anxiety in fourth and fifth grade students?

Hypothesis

The following are the research hypotheses for this study:

Hypothesis 1: There is a statistically significant predictive relationship between demographics, math fact accuracy, and math fact fluency in mathematics anxiety in fourth and fifth grade students.

Hypothesis 2: There is a statistically significant contribution of demographics in predicting math anxiety in fourth and fifth grade students.

Hypothesis 3: There is a statistically significant contribution of overall accuracy in predicting math anxiety in fourth and fifth grade students when controlling for demographics.

Hypothesis 4: There is a statistically significant contribution of overall fluency rates in predicting math anxiety in fourth and fifth grade students when controlling for demographics and overall accuracy.

CHAPTER II

REVIEW OF THE LITERATURE

Mathematics in America

In an effort to improve the American education system, the American Institute for Research (AIR) conducted a report to establish international benchmarks in mathematics which allow American policy makers to monitor our students' educational performance. These reports are important because they help strengthen the American education by discovering the shortcoming of the current system. One report in particular, The Second Derivative: International Benchmarks in Mathematics for U.S. States and School Districts, highlighted the fact students in the United States are not reaching benchmarks for proficiency when compared to their international peers (Phillips, 2009). The report used a common letter grading system to simplify comparisons. A grade of A, B, C, D, or BD (below a D) was utilized to differentiate students' level of proficiency (Phillips, 2009, p. 2). The main overall finding, which has become the driving force to improve American education, is that American students averaged a C+ in mathematics proficiency in fourth grade and a C in eighth grade (Phillips, 2009). This is below the recommended international benchmark referenced in the report. The findings in this report, and others like it, help monitor our country's educational outcomes and provide vital information allowing us to improve our methods. Our educators need to utilize modern advancements in education to address the shortcomings of the current system and foster the growth of our youth into individuals who can be successful in the current work force.

The second major finding of the Second Derivative: International Benchmarks in Mathematics for U.S. States and School Districts is there is a decline in proficiency levels as students' progress through the school. As mentioned in the report's executive summary, "there is a general tendency among states to drop in performance from Grade 4 to Grade 8" (Phillips, 2009, p. 2). Another study, conducted by the U.S. Department of education titled The National Assessment of Education Progress (Perie, et al., 2005), also found that far less students met benchmarks for proficiency in eighth grade when compared to their fourth-grade counterparts. This decline is further exacerbated through 12th grade, where less than 25% of students perform at the proficient level and 61% perform at or above the basic level (Grigg, et al., 2007; NMAP, 2008). This research supports that we have a major problem on our hands especially with STEM occupations projected to grow 10.5% in the next 8 years, while other occupations are projected to grow 3.7% (Cabell, et al., 2021; Fayer, et al., 2017).

A quarter of a century ago, the U.S. led the world in high school and college graduation rates and dominated the research landscape (Ischinger, 2008). Now, the U.S.

has dropped to 20th in graduation rates and ranks number 48 in quality of mathematics and science education (Wilkinson & Bevir, 2007). What is the reason for these steep declines? Burns (1998) attributes American's performance to a culture of math phobia. Statements such as, "Only some people are good at math", "I don't need to be good at math", or "I hate math" are commonly heard in the education system. Yet, mathematics is needed to perform daily living tasks such as cooking, budgeting, deciding how much wallpaper you need to buy, or tipping at restaurants. Whether it be a prerequisite for training or to pass a licensure exam, over 75% of jobs require workers that have proficiency in simple algebra and geometry skills (National Research Council, 1989). Even when making financial decisions or establishing a secure retirement, people who are more comfortable with mathematics are more likely to address these financially decisions earlier with less mistakes (Glass & Kilpatrick, 1998). Addressing this culture of math phobia is vital so our students have the opportunity to excel in fields that produce more job stability, higher overall earnings, and a more competitive edge in the job market.

Mathematics Anxiety

Many students worry about their performance in school and experience academic anxiety; however, most students report these feelings of anxiousness specifically about mathematics. Mathematics anxiety is commonly defined as a feeling of tension, discomfort, worry, and/or frustration during math tasks in a wide variety of ordinary and academic situations (Ashcraft & Moore, 2009; Richardson & Suinn). Math anxiety can range from mild to severe, and can manifest in physiological symptoms (e.g., increased heart rate, upset stomach, increased pain activity) and behavioral symptoms (e.g., avoidance of mathematics classes, putting of mathematics homework, avoidance of mathematics related college majors) (Hackett, 1985; Johnston-Wilder, et al., 2014; Lyons, et al., 2012; Pizzie & Kraemer, 2017). People can experience these symptoms in the workplace, when taking a standardized test, but most commonly in educational settings. In educational settings, these symptoms can have detrimental impacts long-term on student attitudes and success in mathematics. Although the development and etiology of mathematics anxiety is unclear, it is the most common form of academic anxiety in education (Blazer, 2011).

Prevalence

The majority of Americans indicate they experience mathematics anxiety with varying levels of severity (Blazer, 2011). Some children report feelings of anxiety toward mathematics as early as first grade (Sorvo, et al., 2017). It is estimated 38% of the population experiences some level of mathematics anxiety, and approximately 20% of the population experiences high mathematics anxiety (Ashcraft & Moore, 2009; Ashcraft & Ridley, 2005). Perhaps the most extensive data on mathematics anxiety comes from the Programme for International Student Assessment (PISA) assessment across 34 countries participating in the Organisation for Economic Co-operation and Development (OECD). In 2012, PISA came out with a report that approximately 30% of 15- to 16-year-old students across 34 countries reported they get tense when doing mathematics work and they feel helpless when do a mathematical problem; approximately 60% reported they worry mathematics class will be difficult for them (PISA, 2012). This is a considerable portion of our adolescent population who report feelings of helplessness and stress related to mathematics. These numbers are concerning because it can have a snowball effect creating a greater avoidance of STEM related fields.

Variables Related to Mathematics Anxiety

Math anxiety is distinct from other anxieties and has different effects on students. This specific form of anxiety exists in individuals who do not always experience other forms of anxiety (Suinn, 1971). In a sample of college students who were being seen for general academic anxiety, one-third of them reported specific feelings of tension, worry, and apprehension specifically with math. This form of anxiety has negative relationships with cognitive functioning, performance and behaviors related to math. However, it is unclear whether mathematics anxiety causes these declines in performances, or whether these are innate factors that increase an individual's chance of experiencing adverse reactions to math tasks. The following section review proposed variables in the literature related to math anxiety.

Working Memory

Working memory (WM) is described as having a storage and attention component of limited capacity (Swanson & O'Connor, 2009). Baddeley & Hitch (1974) propose three hypothesized purposes of WM: (a) the central executive, which is responsible for processing and preserving information for a short period of time while simultaneously manipulating this information; (b) the phonological loop, which is responsible for verbal information; and (c) the visuo-spatial scratchpad (VSSP) which is responsible for visual and spatial information. WM is responsible for processing and preserving information for a short period of time while simultaneously manipulating this information. Therefore, WM must overcome distractions and quickly generate a response.

The capacity to actively manipulate information in your WM can be disrupted when an individual experiences state anxiety. Feelings of anxiousness compete simultaneously for processing resources (Shi, et al., 2014). Environmental events tend to capture our attention and intrude in our thoughts. Processing resources are typically measured using reading span (RS) tasks; presentation of neutral to-be remembered stimuli (e.g., words or letters) are simultaneously presented with secondary processing tasks (e.g., comprehending sentences) (Conway et al., 2005). For example, to explore the impact of worry and test anxiety on students WM, Shi and colleagues (2014) used RS tasks to examine WM under test related contexts versus neutral contexts. Participants were asked to perform tasks with emotionally neutral material (i.e., letter recall tasks in an emotionally neutral context) while also performing a secondary processing task related to dysfunctional beliefs about test scenarios (i.e., letter recall tasks in a dysfunctional test-related context). Highly test anxious individuals performed poorer on tasks that required dysfunctional test-related material versus emotionally neutral tasks. Working memory was poorer in highly test anxious participants compared to low test anxious participants when performing tasks in dysfunctional test-related contexts relative to performing under emotionally neutral contexts. In this instance, when difficulty was controlled for, test-anxious individuals were more impacted in WM tasks with test-related contexts versus neutral-related contexts, supporting the notion that worrying and intrusive thoughts disrupt your WM.

Following Shi and colleagues (2014), Shi and Lui (2016) further expanded their work by modifying RS tasks to examine working memory capacity in math anxious individuals. Similar to the previous study, WM capacity was examined in math-related contexts as well as in valence-neutral contexts. Consistent with previous results, high math anxious individuals performed poorer on reading span (RS) tasks under the context of math-related sentences compared to low math anxious individuals. Furthermore, there was no difference in performance on RS tasks in valence-neutral contexts between high math anxious individuals and low math anxious individuals. These findings, similar to test-anxiety, suggest that individuals who are math anxious have impaired WM capacity when working on math related tasks.

Performance

In our increasingly high-tech and connected society, "It is important that young children build confidence in their ability to do mathematics" (Furner & Berman, 2003, p. 170). Although the causal relationship is unclear, there is clearly a negative correlation between mathematics anxiety and performance. A meta-analysis examines the impact of mathematics anxiety on mathematics performance on achievement tests and course grades (Hembree, 1990). The correlational research gathered in this study indicates there is a negative relationship between mathematics anxiety and its educational effects. Math anxiety correlates -.34 with math achievement scores in college students, -.30 with high school grades, and -.64 with the desire to take more math classes. Overall, correlation between individuals with high math anxiety and math achievement was -.31. In sum, the higher one's math anxiety, the lower one scores on math achievement tests and grades in math courses, and the less likely one is to choose to take another math course in the future (Ashcraft & Kirk, 2001). Knowing that math anxiety is related to unwanted physiological symptoms and poor performance on math related tasks, it is no surprise it also influences decisions in school related to math (Hackett, 1985).

Behavioral

Heightened negative responses and poor performance on a specific task can lead to avoidance. This avoidance can have a long-term impact on learning. Math anxious students tend to avoid math related situations including homework and preparation for exams (Akinsola, et al., 2007). In study of graduate students and their avoidance of enrolling in statistics courses and procrastination of statistics assignments, it was found approximately 50% of participants reported they nearly always or always procrastinate on assignments related to statistics courses. In addition, the students reported the main reason for procrastination was due to both fear of failure and task aversion (Onwuegbuzie, 2004).

In math, students need to continually practice and master fundamental skills in order to continue development of more complex, multi-step problems (NMAP, 2008; Wu, 1999). When students avoid these opportunities, it can create a cycle of tension and worry, poor performance, and further avoidance of math related tasks; which will in turn may create higher levels of math anxiety (Okoiye, et al., 2017). The number of high school students, particularly girls, enrolling in advanced math courses is declining (Mack & Walsh, 2013). In an informative meta-analysis, Hembree (1990) also examined math anxiety related to student's avoidance of math courses. High school students with high math anxiety took fewer math courses and were less likely to pursue more math courses in high school and college. Additionally, students in remedial math courses in college showed higher levels of math anxiety versus students in more advanced math courses. These avoidance behaviors are troubling because they can influence one's career path.

STEM Occupations. Since 1990, STEM occupations have grown 79% from 9.7 million to 17.3 million (Pew Research Center, 2008). STEM occupations include computer, architecture, physical scientists, life scientists, and health-related occupations. Mathematics is the gateway for STEM careers and advancement in modern technology (see Roman, 2004). In recent years, there has been a push toward understanding the decline of interest in STEM careers (Johnston-Wilder, et al., 2014).

A longitudinal study was conducted over seven years to gain a better understanding of the developmental trajectories of math anxiety with a sample of 3116 seventh grade students (Ahmed, 2018). Each year, participants completed a math anxiety questionnaire and took an achievement test. At the end of the study, participants were also asked about their occupation. Students fell into four-cluster categories for trajectory of math anxiety: (a) *Consistently Low* (34.68%); (b) *Decreasing* (23.72%); (c) *Increasing* (21.9%), *and* (d) *Consistently High* (20.1%). Students in the *Consistently Low* and the *Decreasing* math anxiety clusters were found to be seven times more likely to employed in the STEM field. Unfortunately, this also supports the notion that highly math anxious students are less likely to develop the confidence and skills necessary to pursue STEM related careers.

In 2014, the UK began to recognize the declined interest in math majors and STEM careers. England in particular was facing problems in recruiting more STEM apprentices. So, a research study was conducted to explore the extent in which math anxiety played a role in STEM apprentices' recruitment and progression (Johnston-Wilder, et al., 2014). STEM and nonSTEM apprentices in the surrounding areas were sampled using the Mathematics Anxiety Scale (MARS), the Mathematical Resilience Scale, and were asked questions relating to choose of apprenticeship. Approximately 30% of respondents indicated noticeable impact of their math anxiety, which is roughly similar to the general population (Ashcraft & Moore, 2009; Ashcraft & Ridley, 2005). Math anxiety was more prevalent in nonSTEM apprentices; furthermore, a quarter of nonSTEM apprentices reported that their feelings about math directly impacted their choice in apprenticeship. This study found that math anxiety across apprenticeships was roughly equal to the general population, which impacted choice in apprenticeship. This declined interest in STEM is concerning because to succeed in this new information-based and highly technological society "students need to develop their capabilities in STEM to levels much beyond what was considered acceptable in the past" (National Science Board, 2007, p. 2).

Causes of Math Anxiety

Individuals who experience math anxiety can have high discomfort and worry related to math tasks. Avoiding math seems like the natural response, but what causes math anxiety is unclear. Nevertheless, potential causal or reciprocal variables include personality variables (e.g., self-esteem and motivation), cognitive variables (e.g., working memory), environmental variables (e.g., parent and teacher response), and performance on math tasks.

Personality

Personality factors may influence how a child reacts to math related situations. Self-esteem, more specifically self-concept and self-efficacy, have a negative relationship with math anxiety. Self-concept can be described as one's beliefs about their competence in an academic domain compared to a standard or other's knowledge (Marsh, 2011). Self-efficacy is one's belief that through their own action they can be successful in an academic domain (Marsh, 2011). In the 2012 PISA report, results from 15- and 16-year-old students showed that self-concept and self-efficacy in math have a positive relationship with math performance and a negative relationship with math anxiety. However, the directionality of this relationship is unclear. Students who are performing well may have a better developed sense of self-concept and self-efficacy due to their success; in turn poor performance may lead to lower self-concept and self-esteem in those students.

Environment

Variables in a child's environment can shape the way they view and respond to math tasks. Learning history and how adults in their environment respond to and teach math may be a source a child's math anxiety. Children spend the most time with their parents and teachers, and these adults can play a major role in shaping a student's attitudes and performance on academic tasks (Eccles et al., 1990; Yee & Eccles, 1988; Tiedemann, 2000; Jacobs, 2005).

Parents. Although parents are not the ones teaching students math, their beliefs and behavior may have an impact with how their children feel about math. Parents are the ones who help their children with math homework and complete mundane math related tasks daily (i.e., tipping, household budget). If a parent experiences math anxiety this could observed by and communicated to their child. Casad and colleagues (2015) wanted to study parental math anxiety as an antecedent to child math performance and attitudes toward math. Data was collected from 683 parents and child dyads which examined parental math anxiety, child math anxiety, math class GPA, and math education behavioral intentions. More specifically, they examined same-gender parent-child dyads. Overall, results supported the hypothesis that parents' anxiety may be an antecedent to children's math anxiety, math GPA, and math behavioral intentions. Additionally, the most significant relationship was between Mother-Daughter dyads. When mothers' math anxiety was low, their daughter's math anxiety tended to be low as well and had more positive math outcomes (i.e., higher GPA, higher self-efficacy, higher math behavioral intentions). These results support previous literature that parental math anxiety is related to and may be an antecedent of child math anxiety (Gunderson, et al., 2012; see Maloney et al., 2015).

Teachers. In addition to parental math anxiety, teacher's comfortability with teaching math concepts and their own math anxiety can have an impact on student's achievement and attitudes towards math (Furner & Berman, 2003, Ring et al., 2000; Vinson, 2001). Compared to other professions (e.g., business, health science), elementary teachers report high levels of math anxiety (Bryant, 2009; Hembree, 1990). This can impact their comfortability with teaching math concepts and hinder student learning (Beilock et al., 2010; Stoehr, 2017). Teacher math anxiety has a negative relationship with teacher's belief in their skills and abilities to teach math well to their students (i.e., academic self-efficacy; Swars, et al., 2006). This belief can have an impact on the methods teachers use to teach math concepts (Karp, 1991). Teacher who are less comfortable with teaching math rely on lectures, seat-work, and whole-group instruction versus more in-depth, individualized, and direct ways to teach mathematics (Karp, 1991).

Beilock and colleagues (2010) examined how female teacher's math anxiety might impact student math anxiety and achievement over the course of the school year, particularly in female students. They explored students' beliefs about math and math achievement at the beginning of the year, when they had little exposure to their teacher, and then again in the last two months of school. To examine adherence to traditional gender stereotypes that boys are good at math and girls are bad, they also were told two gender-neutral stories. The first story was about a student who was good at math and the second story was about a student who was bad at math. Then students were asked to draw these students. At the beginning of the year, there was little to no relation between teachers' math anxiety and student math achievement. By the end of the year, there was a significant relationship between teachers' anxiety and female math achievement ($r = -0.28$, $p = 0.022$), but not so much male math achievement ($r = -0.04$, $p = 0.81$). Additionally, female students who indicated beliefs toward traditional gender stereotypes were significantly more likely to perform poorly on math tasks at the end of the year. These findings were not seen at the beginning of the school year, suggesting that teacher anxieties had an impact on student, particularly female, math achievement and attitudes towards mathematics (Beilock, et al., 2010).

Performance

There is a clear negative relationship with performance on math tasks and math anxiety. However, there is debate about the directionality of the relationship between performance and math anxiety. Simply put, does poor performance cause math anxiety, or do high levels of math anxiety interfere with cognitive functions which results in poor performance. Two theories have been proposed to explain this relationship: The Cognitive Interference Theory (Wine, 1980) and The Deficit Theory (Tobias, 1986).

Cognitive Interference Theory. The Cognitive Interference Theory (Wine 1980, 1971) was one of the first proposed theories addressing the causes of math anxiety. This theory proposes that students with high anxiety may have acquired the knowledge, but that retrieval of the content on which they are examined on is diminished by their anxiety. In other words, high levels of math anxiety interfere with cognitive processes, which then causes difficulty in recalling prior knowledge resulting in poor performance. Hembree's (1990) meta-analysis supports the notion that mathematics anxiety decreases performance in math. This conclusion is made because: (a) "high achievement consistently accompanies reduction in mathematics anxiety"; and (b) "treatment can restore the performance of formerly high-anxious students to the performance level associated with low mathematics anxiety" (p. 44).

Shi and colleagues (2014, 2016) earlier mentioned studies provide support for the Cognitive Interference Theory. In both general academic and math related contexts, when students with high math anxiety had more difficulty performing in math-related contexts compared to valence-neutral contexts. Students had impaired WM capacity on reading span tasks when working on math related tasks.

The Deficit Theory. In contrast, the Deficit Theory (Tobias, 1986), proposed that debilitating effects on test performance was due to a deficit in study skills, prior knowledge, and/or awareness of poor performance in the past on specific academic tasks. Ma and Xu (2004) sought to determine the causal relationship between math anxiety and performance to inform appropriate educational practice and treatment of academic anxieties. Furthermore, they wanted to dismantle the notion that, “if students do not fare well in attitude, they cannot achieve well” (Ma & Xu, 2004, p. 257). One of the few longitudinal studies in this area, researchers gathered data from a 6-year study of math and science education in the U.S. It was found that prior achievement significantly predicted later, and poorer, achievement across grades 7-12. In contrast, prior attitude toward math did not significantly predict later achievement. Supporting the Deficit Theory (Tobias, 1986), Xa and Mu (2004) state that “if students achieve well in mathematics, their attitudes can be enhanced” (p. 277). As for practical implications, if educators focus on strategies that improve student’s achievement, it can help foster a positive attitude toward math and decrease math anxiety (Xa & Mu, 2004).

Expanding on this field of research, Cates and Rhymer (2003) took a closer look at the relationship between mathematics anxiety and mathematics performance by examining mathematics performance at a more advanced stage of learning proposed by Haring and Eaton (1978). Ma (1999) noted that researchers who measure performance using only accuracy measures or standardized achievement tests tend to find a weaker relationship between mathematics anxiety and mathematics performance. In these instances, they are using an accuracy as a broad measure of academic performance, which alone may not be the best measure for mathematics achievement (Binder, 2003; Skinner & Schock, 1995). Cates and Rhymer (2003) measured mathematics performance using accuracy and fluency-based measures to see if mathematics anxiety is related to a more advanced stage of learning (i.e., fluency). Fifty-two college students completed mathematics anxiety measures and then completed five individually timed single skill mathematics probes that were scored based on accuracy and fluency measures. Results showed that students with low math anxiety performed better on fluency measures across all five math probes compared to students with high math anxiety. In contrast, students with high and low anxiety did *not* have a statistically significant difference in performance on accuracy measures. Cates and Rhymer (2003) suggest that the relationship between math anxiety and math performance can be better understood in relation to Instructional Hierarchy (1978).

Instructional Hierarchy

Haring and Eaton (1978) offer researchers, practitioners, and educators with four sequential phases of skill development known as the "Instructional Hierarchy" (Rivera & Bryant, 1992). Originally, the Instructional Hierarchy was applied broadly to education in general, but it can also be utilized to examine the steps involved in learning mathematics. Learning can be defined as "the ability to perform new skills in progressively more complex situations" (Haring & Eaton, 1978, p. 23). As students' progress through skill development, educators can be more efficient in planning instruction by referencing a systematic guide when selecting instructional procedures. Teachers can prevent the use of random unsystematic procedures that negatively influence educational outcomes by utilizing the Instructional Hierarchy. The four phases proposed by Haring and Eaton (1978) include acquisition, fluency building, generalization, and adaptation. The following sections define each phase of skill development, discuss the importance of each, and provide instructional strategies that educators can use when students' progress through each phase of learning.

Acquisition

Acquisition is the first phase involved in learning a new skill. It is defined as the period between "the first appearance of the desired behavior and the reasonably accurate performance of that behavior" (Haring & Eaton, 1978, p. 25). Acquisition prioritizes accuracy above all else. Students must learn how to repeatably demonstrate a skill correctly before they can incorporate the skill into their behavioral repertoire. All other steps in the instructional hierarchy depend on the foundation laid by acquisition. You must attempt a step before you can learn how to walk. Acquisition is the first step. Educators should rely on explicit instructional strategies to facilitate the acquisition of a new skill. When teachers first introduce a new skill to the general core instruction, it is essential that the concept of explicit instruction be incorporated into their educational strategy (Archer & Hughes, 2010; NMAP, 2008).

Explicit Instruction. Explicit instruction is an evidence-based practice that helps students maximize their academic growth by delivering effective systematic instruction (Archer & Hughes, 2010; Doabler & Fien, 2013; Gersten, 1988; Marin & Halpern 2011). The National Mathematics Advisory Panel (NMAP, 2008) recommends that explicit instruction in mathematics include: (a) the teacher providing clear models for solving a problem type using an array of examples; (b) students receiving extensive practice in the use of newly learned strategies and skills; (c) providing students with opportunities to think aloud; and (d) ensuring students are provided with extensive feedback (p. xxiii). Explicit instruction can also support the acquisition of new skills by utilizing the concepts of demonstration, modeling, and a narrow curricular scope. As discussed later in this report, this instructional approach has been applied to more than core-instruction alone. Explicit instruction is seen as an essential component when teaching students that struggle to learn mathematical skills (Doabler & Fien, 2013; NMAP, 2008). Once a learner is capable of accurate performance of a skill, they may continue to the next step of the instructional hierarchy: fluency.

Fluency

Fluency is the second phase involved in learning a new skill. Fluency can be defined as demonstrating a new skill with a level of competence which shows mastery. This degree of proficiency allows students to maintain skills for an increased length of time and generalize concepts learned to acquire new related skills (Haring & Eaton, 1978, p. 27). The transition from acquisition to fluency can be illustrated by the adage mentioned earlier about a child performing their first steps. Once a child can accurately make steps, they can begin to link their steps together. At this point, we can begin to compare the child's walking to their peers and measure more objectively how well they are doing. If a child repeatedly falls while walking, it is logical to wait until the child can walk without aid before moving onto more complex tasks like running. Once a child can walk with little to no mistakes, the focus shifts toward speed (if this is the target skill you are looking to improve). Fluency building (i.e., proficiency) is a fundamental stage that often gets overlooked by educators if a learner demonstrates accuracy of a task. Haring and Eaton (1978) state, "It is not enough merely to perform a skill; one must be able to perform it fluently and competently if the skill is to serve one well in all circumstances" (p. 27). Fluency can be enhanced by providing students with opportunities to respond, performance feedback, goal setting, and utilizing performance-based reinforcement contingencies (Codding, et al., 2016).

Overlearning. Overlearning, also known as maintenance, was originally included in Haring and Eaton's instructional hierarchy as a component of the fluency phase. Some current researchers designate maintenance as the third phase of the Instructional Hierarchy instead of grouping it together with fluency. As a standalone phase, maintenance can be defined as the "accurate and fluent performance with a skill or concept over time, even when learning a new more advanced skill or concept" (Codding, et al., 2016, p.10). It could also be argued that the process of maintenance is occurring at all phases of the Instructional Hierarchy. Maintenance is important because it prevents the decay of a learned skill and decreases the amount of mental power required to perform the skill. Repeated practice, a strategy for building fluency, is the most common procedure to facilitate maintenance of a skill (Haring & Eaton, 1978). Research indicates that active and repeated responding increases the likelihood that students will permanently remember new tasks (Anderson, 2008). Maintenance is a key component of learning because the ability to perform a skill fluently over the passage of time indicates mastery of that skill.

Generalization

The third phase of the instructional hierarchy is known as generalization. This phase can be defined as the demonstration of fluent responding in a different setting, with new people, or in unfamiliar situations. Generalization allows students, who can fluently complete basic math operations, to accurately respond to similar math operations presented in a word problem. Haring and Eaton (1978) define generalization as "Performing a skill in response to new stimuli similar to those used during instruction" (p. 30). Generalization is important because it allows students to apply the skills they learned in school throughout their lives. Educators can incorporate generalization into the classroom by preparing a range of tasks with different levels of complexity that force students to utilize a learned skill. They can also provide students with instructional prompts to encourage generalization or slowly withdraw adult support (Codding, et al., 2016).

Adaption

Skill adaption is the final stage of the instructional hierarchy. Adaption can be defined as the ability to modify skills and concepts in a novel way. Problem-solving is a great example of adaptation. Solving a new unfamiliar problem requires students to utilize previously mastered skills and apply them in modified ways. Haring and Eaton (1978) use a simple example to explain the difference between generalization and adaption. They explain that teaching a child to use "Please" and "Thank you" in a variety of appropriate contexts (e.g., at the store, in the classroom, at home) would be generalization, but the child modifying that those expressions (e.g., I would appreciate it if… or I am grateful) would be a demonstration of skill adaption (Haring & Eaton, pp. 31-32). Skill adaption can be taught to students by providing them with opportunities to use previous knowledge in foreign situations and providing them with feedback on skill application.

John Wooden, a famous basketball coach stated, “Skill, as it pertains to basketball, is the knowledge and the ability, quickly and properly, to execute the fundamentals. Being able to do them is not enough. They must be done quickly. And being able to do them quickly isn’t enough, either. They must be done quickly and precisely at the same time. You must learn to react properly, almost instinctively” (1988, p. 87). In this example, John Wooden defines mastery of a skill beyond just having the ability to play basketball. When comparing this example to the Instructional Hierarchy, one needs: (a) the ability and knowledge (i.e., acquisition); (b) the ability to execute fundamental skills quickly and properly (i.e., fluency); (c) needs to be able to react properly in all situations (i.e., generalization); and (d) act almost instinctively in novel situations (i.e., adaptation)

Fluency Building

Out of all the Instructional Hierarchy phases of learning, fluency is often overlooked and underappreciated. Many educators forget a critical component of fluency. Most remember that fluency is defined as accurately demonstrating a task, but a lot forget that the definition also involves a speed component as well. Student’s ability to learn complex skills is negatively impacted by focusing solely on acquisition. This is particularly true for achieving fluency of basic computation facts (i.e., addition, subtraction, multiplication, division) and learning higher-level mathematics (Anderson, 2008; Brown & Bennett, 2002; Cates & Rhymer, 2003; Glover, et al., 1990; Moors & De Houwer, 2006). To achieve a quick and accurate retrieval of facts (also known as computational fluency), emphasis must be placed on the automatic recall of basic math facts. Students, who effectively utilize these permanently installed responses, are able to attempt more complex math problems (Glover, et al., 1990; NMAP, 2008). Core knowledge in arithmetic computations allows students to use those limited resources towards mathematical learning and skill acquisition. Computational proficiency (i.e., fluency) is essential because it provides a foundation for students to benefit from instruction. According to Kroesbergen and Johannes (2003), "Children who struggle with math are unable to master the four basic operations before leaving elementary school., and thus, need special attention to acquire the skills" (p. 98). It is vital that educators understand the true definition of fluency and incorporate it into their instructional strategies so students can reap the rewards.

Fluency in Education

In most schools in America, students are graded, and pass courses based on percentage correct calculations. This is an accuracy-only measurement of knowledge, and it is often used to determine whether a student meets mastery criteria for a skill. Competency in these areas is based on acquisition of a skill; however, it ignores being able to execute that skill quickly and accurately. When compared to other fields, such as medicine, professional sports, music, dance, computer engineering, and most other fields, this is not the case. Similar to John Wooden's (1998) example for basketball, one needs to be able to do more than execute a play correctly to be successful. Improvisation in creative performance or in medicine requires the ability to execute fundamental skills quickly and effortlessly in novel scenarios without thought. This is also true for solving a complex math problem. However, this fact seems to be overlooked in our education system.

Some researchers would define fluency as a true representation of mastery (see Binder, 2003). Increased fluency of a task aids in acquisition of higher-level tasks and increases retention of the discrete skill and the composite skill long-term (Bucklin, et al., 2000). Bucklin and colleagues (2000) compared the effects of fluency training versus accuracy training on acquisition and retention of component skill (i.e., Hebrew and Arabic symbols) and composite skills (i.e., Hebrew symbols written as arithmetic problems and answering in Arabic numerals) of a novel task. College students were randomly assigned to the accuracy or the fluency group. All students were initially trained on the component skill using flash cards. This part of the training ended when participants reached 100% accuracy for four consecutive trials. The accuracy-only group did not receive any further training. The fluency training group continued training sessions until they reached skill-based fluency criteria. The fluency training group had much higher performance on higher level, composite tasks immediately after and 16 weeks following the training in comparison to the accuracy training group. Immediately following training, the fluency group was able to answer approximately eight more items correctly per minute compared to the accuracy group, and this gap was exacerbated when retention was assessed. Additionally, accuracy component and composite tasks was lost in the accuracy group in follow-up sessions. Immediately after training the fluency and accuracy groups were 100% on component tasks; four weeks after training the fluency groups was 76.3% accurate relative to the accuracy group who was 15.8% accurate on component tasks; 16 weeks after training the fluency group was 64.2% accurate and the accuracy group was 13% accuracy on component tasks (Bucklin, et al., 2000)

Using procedures that measure accuracy only impose ceilings on students limiting their opportunities to practice and master discrete skills that are vital to learning more complex skills. Educators cannot distinguish mastery of a skill based solely on accuracy measurements. By giving students more opportunities to practice discrete skills, they are then able to improve long-term maintenance of skills (Bucklin, et al., 2000), increase their endurance and attention toward the task (Binder; 1979, Binder & Sweeney, 2002), and can learn more complex skills easier (Beck, 1979; Johnson & Layng, 1992).

Gap between research and practice. As discussed earlier, students are not meeting mathematical grade-level benchmarks consistently. This failure worsens as students' progress through school. NMAP (2008) notes a major difference between U.S. curricula and top performing countries is the number of mathematical topics and concepts students are expected to learn at each grade. In addition, the U.S. does not utilize the same curriculum across states, much less across districts. Other top performing countries tend to teach fewer mathematics topics and concepts and require greater in-depth knowledge. NMAP (2008) recommends the Benchmarks for Critical Foundations in Table 1.1 as guidance for states and school districts for criteria at each grade level to encourage cohesive development of skills across the U.S. These recommendations were develop based on comparison to national and international curricula.

Table 1.1 *Benchmarks for Critical Mathematical Foundations*

Skill	Grade	Criteria
Fluency with Whole Numbers	3	Proficient with addition and subtraction of whole numbers.
	5	Proficient with multiplication and division of whole numbers
Fluency with Fractions	4	Able to identify and represent fractions and decimals, and compare them on a number line with other common representations of fractions and decimals
	5	Proficient with comparing fractions and decimals and common percent, and with addition and subtractions of fractions and decimals
	6	Proficient with multiplication and division of fractions and decimals
	6	Proficient with all operations involving positive and negative integers
	7	Proficient with all operations involving positive and negative fractions
	7	Able to solve problems involving percent, ratio, and rate and extend this work to proportionality

Note. Adapted from National Mathematics Advisory Panel. (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel.* Washington, DC: U.S. Department of Education. https://www2.ed.gov/about/bdscomm/list/mathpanel/report/final-report.pdf

Using statistics derived from an online database in 2012 (Renaissance Learning, 2011) upon entering seventh grade, less than 50% of students demonstrated fluency in multiplication facts, and less than a 35% demonstrate fluency in the division. The NMAP (2008) recommendations indicate that students should have multiplication mastered by the end of fifth grade. This does not mean that students are unable to compute basic math problems, but it does signify a lack of fluency (or proficiency). After fifth grade, there is little emphasis on these facts, which prevents many students from ever mastering these skills (Isaacs & Caroll, 1999).

Achieving automaticity should be an integral component of early mathematics, however, the NMAP points out that, "Few curricula in the United States provide sufficient practice to ensure fast and efficient solving of basic fact combinations and execution of the standard algorithms" (NMAP, 2009, p. 26). Doabler and Fien (2012) investigated the lack of emphasis placed on basic math computation by evaluating the contents of textbooks used in grades two and four. Unfortunately, the textbook they evaluated demonstrated a lack of adherence to principles of instruction, including: (a) review of prerequisite skills; (b) opportunities for explicit and systematic instruction; and (c) sufficient practice and cumulative to achieve mastery of topics (Doabler & Fien, 2013). Teachers of higher-level math topics have also noticed a lack of mastery in skills needed to prepare students for more complex tasks. A survey of high school algebra teachers indicated that background preparation for Algebra 1 was weak and that "students need to be better prepared in basic math skills" (NMAP, 2009, p. 9).

Computational fluency seems to be sometimes supplemental rather than foundational in the U.S. curriculum. This contributes to students experiencing mathematical difficulties at a higher rate. Failure to achieve computational proficiency impedes on the students' ability to understand higher-level concepts in mathematics (Bryant, et al., 2008). Researchers are confident that fluency building should be an integral part of mathematics instruction at all grade levels. However, there is still a gap between research and its application in the appropriate settings. Researchers realize that most educators are hesitant to take on the additional responsibility of adding evidencedbased instructional interventions to their base curriculum. Many educators are struggling to get through their curriculum effectively as is. Researchers must focus on providing easy to implement solutions that take the pressure off teachers.

Improving computational fluency, thankfully, can be very simple. The easiest way to improve student mathematics performance is practice and lots of it. The U.S. Department of Education (Gersten et al., 2009) recommends that Response to Intervention (RtI) schools have "Interventions *at all grade levels* [that] devote about 10 minutes in each session to building fluent retrieval of basic arithmetic facts" (p. 37). The panel views such practice as critical at every grade level regardless of where students' skill level stands. Focusing on cumulative review helps students build and maintain mathematics fluency.

Benefits of Fluency

Fluency enriching instructional strategies are beneficial to students because they free up working memory, increase opportunities to respond, increase reinforcement for the desired task, and decreases the student's effort. This provides more students the opportunity to climb higher up the Instructional Hierarchy and eventually master skill generalization and adaption.

Working Memory. As described earlier, working memory (WM) has a storage and attention component of limited capacity (Swanson & O'Connor, 2009). WM is responsible for processing and preserving information for a short period of time while simultaneously manipulating this information. WM must overcome distractions and quickly generate a response. When students are instructed to perform WM tasks, they must pull information from some task elements while inhibiting distracting elements to accurately complete the task. The capacity to actively manipulate things in our WM is limited and can be a constraint when trying to learn new procedures, skills, or concepts (Menon, 2010; Rivera, et al., 2005). When students can apply elements of knowledge automatically and without reflection, they can use those freed-up cognitive resources to take on more challenging tasks (Brown & Bennett, 2002; Moors & De Houwer, 2006).

Fluent mathematical computation and problem-solving skills have consistently demonstrated a positive correlation with WM (Bull & Scerif, 2001; Swanson & Beebe-Frankenberger, 2004; Tolar, et al., 2009). Working memory can be freed up when students are able to automatically recall stored information. This allows students more mental capacity to address more difficult problems. For example, when breaking down the steps of a long division problem, a student needs to use a combination of addition, subtraction, multiplication, and division. A lack of automaticity makes novel tasks nearly impossible for students to complete in a timely manner. Research supports the notion that achieving fast, accurate, and effortless recall of computation facts, allows students to focus more energy on more complex aspects of a math problem (NAMP, 2008) and learn higher-level math skills with less effort (Pellegrino & Goldman, 1987; Tolar, et al., 2009).

Opportunities to respond. Opportunities to respond is defined as the number of times a student is given the chance to actively complete an academic task (i.e., practice) (Gettinger, 1995). Actively practicing a skill increases mastery of that skill. This is a common-sense strategy that is used across all domains of skill development (e.g., sports, music, meditation, etc.). Everyone knows the old adage “practice makes perfect”.

Students maintain learning over time by actively responding to antecedent stimuli. Providing more opportunities for an individual to practice a skill allows for more opportunities for stimulus-response-feedback (Skinner, 1998). Increasing opportunities to respond has a positive impact on accurate responding and learning rates (Skinner, 1998). When students engage in fluent rates of academic responding, it increases their opportunities to respond. This allows students to engage in additional learning opportunities and improve their academic performance.

Increased reinforcement. Students who can quickly and accurately complete a task are reinforced at a higher rate than those that complete the task slowly and accurately. From a behavioral perspective, increasing rates of reinforcement increase the likelihood that a student chooses to engage in a task. Students may avoid working on difficult tasks because it takes them longer to complete those tasks, which results in a delay to reinforcement. Skinner (1998) further explored the relationship of behavioral reinforcement by comparing a student who finds reading fun with a student who does not. A student who can fluently read a text passage in 10 minutes will find more enjoyment from reading than a dysfluent reader who reads the same passage in 30 minutes. Reading requires more effort for the latter student and therefore decreases the reinforcement received from reading the same passage. Additionally, the student who can fluently read is more likely to obtain external reinforcements at a higher rate. Reinforcements can take the form of increased free time or positive praise from a teacher. Students who can complete academic tasks quicker are reinforced at higher rates. It is more likely that those students choose to complete assignments (Martens, et al., 1992; Zaman, et al., 2010).

In a study by Zaman and colleagues (2010), the effects of reinforcement and fluency interventions on students' choice behavior was explored. The study consisted of three phases: (a) the first phase of the study, researchers conducted a choice assessment prior to any fluency interventions; (b) the second phase consisted of implementing an intervention that increased fluency; and (c) in the third phase, researchers examined the changes in choice pattern when the same choices were available in the first phase. They initially found that prior to fluency training all students chose to spend more time on the task which required less effort. However, once reinforcement was increased, students shifted towards spending more time on high effort tasks (Zaman, et al., 2010). This study demonstrated how fluency building increases students' opportunities to obtain positive reinforcement for task completion. Additionally, it supports the notion that increasing reinforcement subsequently increases the likelihood a student chooses to engage in an activity.

Effort. The previous study supported the notion that increasing reinforcement also increases the likelihood that a student chooses to engage in a task. The researchers also wanted to examine the effects of fluency training on choice behavior. They found that after the second phase, which consisted of implementing fluency interventions, participants preferred to engage in high effort tasks compared to before fluency training (phase one). Zaman and colleagues (2010) hypothesized that students could complete high effort tasks more quickly and accurately after they received fluency training. This leads to increased reinforcement for high effort tasks over low effort tasks (p. 79). Choice behavior is heavily influenced by the effort required to perform a task. If a student is presented with a task that requires high-effort and they receive low reinforcement, they are less likely to choose to complete that task. A student who can fluently perform a task, however, may be more likely to choose to engage because it requires less time and effort.

Fluency Building in Mathematics

Students who are fluent in basic math facts show higher task completion rates and receive more opportunities to practice their skills which further enhances their accuracy, fluency, and maintenance. Just as reading fluency is a critical element in the development of reading comprehension, computational fluency is a critical element in the development of mathematics skills (Gersten, et al., 2005). A student who cannot add, subtract, multiply, and divide accurately and efficiently fall behind their peers and fail to advance their mathematical skills. Computational fluency in mathematics is a fundamental skill in developing higher-level mathematical skills and concepts (Gersten, et al., 2005; Tolar, et al., 2009). Timed practice, also known as explicit timing, is a key instructional strategy that fosters the development of computational fluency.

Explicit timing. There is an array of interventions that can be utilized to support students with mathematical inadequacy. Explicit timing is a simple and effective intervention available to students who demonstrate accuracy of a mathematical skill (Codding et al., 2011, 2009, 2007; Methe, et al., 2012; Rhymer et al., 1999, 2002). Explicit timing is an antecedent stimulus that increases students' rates of accurate academic responding (Skinner, 1998). Timed procedures provide students with increased opportunities to respond to basic math computation problems, which deters students from calculating problems through counting and in turn reinforces decreased response time

(Isaacs & Carroll, 1999). Teachers can easily add timed procedures to their normal instructional strategy, but some teachers remain hesitant.

There is a large volume of evidence supporting explicit timing, however, some educators are tentative to implement this strategy. They believe that timed tests cause mathematics anxiety and can demotivate students. Grays and colleagues (2017) found that there was a significant linear relationship between a student's mathematics anxiety and mathematics performance. Students with high mathematics anxiety completed fewer digits correct per minute and vice versa. Additionally, students who had high mathematics anxiety had significantly lower accuracy (2017). However, this outcome is not surprising given the low accuracy (or acquisition) of the task. It is not recommended that students' progress to the fluency phase until the targeted skill is mastered (Codding et al., 2007). By appropriately advancing through the instructional hierarchy, students will avoid the associated mathematics anxiety and poor performance that accompanies students who advance before they are ready. When skills are matched appropriately to tasks and not directly attached to grades, research has found that students enjoy timed tests (Miller, et al., 1995). Educators need to thoroughly assess the mastery of a skill before their students can start explicit timing exercises.

CHAPTER III

METHODS

This chapter will describe the methodology for the study. The purpose of this study is to gain a better understanding of the relationship between mathematics performance and mathematics anxiety, and to explore if measures of fluency add a significant contribution to predicting mathematics anxiety.

Participants

Students in fourth and fifth grade at two intermediate schools will be recruited for the proposed study. The participating school will be located in central Oklahoma. In predictive correlation studies, Warner (2013) suggests a minimum of 106 participants for a regression with two predictor variables. Approximately 200 students will be recruited for this study. This would allow for the predictor variables to have enough power to provide more precise estimates (Warner, 2013). Students whose parents' consent will be given the opportunity to participate. Assent will be obtained from students at the time of the research study. No exclusionary criteria will be utilized for children whom consent is obtained. This would allow for a large sample population and employ a stronger participant selection procedure as recommended in previous studies (Cates & Rhymer, 2003).

Research Design

For the proposed study, a non-experimental, predictive correlation research design will be utilized to examine the relationship between the predictor and outcome variables. In this study, there will be no manipulation of variables or interventions. The purpose of this study is to examine the strength of the relationship between performance on mathematics probes and mathematics anxiety when a more sensitive measure is used to assess mathematics performance. Due to the exploratory nature of the study and the variables used, a non-experimental predictive correlation is proposed as the most appropriate research design.

Measures

Predictor Variables

Fluency. Fluency is a measure of the rate in which a student can solve a problem. Student's digit computed correctly per minute (DCPM) will be assessed using Curriculum Based Measurement (CBM; Shapiro, 1996). CBM procedures for administration and scoring will be used (Deno & Mirkin, 1977; Kelley, et al., 2008; Shapiro, 1996; see Appendix A). CBM will be used to gather low-inference information from the direct sample students complete (Kelley, et al., 2008). This is a more sensitive measure of student performance compared to traditional measures (Kelley, et al., 2008). Rather than scoring students based on the number of problems completed correctly, they are scored based on number of digits completed in each set. Fluency will be measured across each probe (i.e., addition to 18, subtraction from 18, multiplication to 81, and division from 81). Total number of digits correct per minute across each probe will be summed and divided by four to determine overall DCPM (Cates & Rhymer, 2003; Grays, et al., 2017).

Students will be assessed on a range of grade-level appropriate, single-skill mathematics probes appropriate for fourth and fifth graders. The scope of the skills assessed for the students were determined by matching probe difficulty with NMAP (2008), Common Core, and Oklahoma's academic standards (OSED) recommended benchmarks for student proficiency (see Table 2.1). By matching probe difficulty to across common standards, it can ensure that student's performance will be assessed on skills in which they should be accurate. Table 2.1 below depicts the scope and rationale of skills assessed for students in fourth and fifth grade.

Table 2.1 *Single Skill Scope and Rationale*

Grade	Skills Assessed	Purpose
4	Addition to 18 Subtraction from 18 Multiplication to 81 Division from 81	"By the end of Grade 3, students should be proficient with addition and subtraction of whole numbers" (NMAP, 2008, p. 20) "Fluently add and subtract multi-digit numbers using the standard algorithm" (Common Core Standards, 2010) "Demonstrate fluency with multiplication and division with factors up to 12" (OSDE 2016, p. 20) "Multiply a whole number of up to four digits by a one-digit whole number, and multiple two-digit numbers" (Common Core Standards, 2010)

		"Find whole-number quotients and remainders with up to four-digit dividends and one-digits divisors" (Common Core Standards, 2010)
5	Addition to 18 Subtraction from 18 Multiplication to 81 Division from 81	"By the end of Grade 5, students should be proficient with multiplication and division of whole numbers" (NMAP, 2008, p. 20) "Fluently multiple multi-digit whole number using the standard algorithm" (Common Core Standards, 2010) "Divide multi-digit numbers by one- and two-digit divisors, using efficient and generalizable procedures…" (OSDE, 2016, p. 23) "Find whole-number quotients of the whole numbers with up to four-digit dividends and two-digit divisors, using strategies based on place value, the properties of operations, and/or the relationship between multiplication and division" (Common Core Standards, 2010)

Note. Adapted from National Mathematics Advisory Panel. (2008). Foundations for success: The final report of the National Mathematics Advisory Panel. Washington, DC: U.S. Department of Education. https://www2.ed.gov/about/bdscomm/list/mathpanel/report/final-report.pdf; Oklahoma State Department of Education (2016). Oklahoma Academic Standards for Mathematics. https://sde.ok.gov/sites/ok.gov.sde/files/documents/files/OAS-Math-Final%20Version_3.pdf; National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). Common Core State Standards. Washington, DC: Authors.

Accuracy. Accuracy is the measure of the closeness of agreement between the result of a measure and a true value of the variable being measured. For this study, accuracy will be measured by scoring the number of digits correct divided by the total of digits completed across a mixed math probe. Students were given 10 minutes to complete the mixed math probe and accuracy will be emphasized in the administration instructions. Students will only be scored on problems they have completed. This ensures noncompletion due to lack of fluency does not negatively impact accuracy scores (Cates & Rhymer, 2003, Grays, et al., 2017).

Outcome Variable

Mathematics Anxiety. There are several mathematics anxiety self-report instruments used to measure mathematics anxiety including the Mathematics Anxiety Rating (MARS; Richardson & Suinn, 1972), the Fennema-Sherman Mathematics Attitude Scale (FMAS; Fennema & Sherman, 1976), and the Math Anxiety Questionnaire (MARS; Wigfield & Meece, 1998). In the proposed study, mathematics anxiety will be measured using a self-report survey. The self-report instrument that will be used in this study is this Mathematics Anxiety Scale for Children (MASC; Chiu & Henry, 1990; see Appendix B). Chiu and Henry (1990) adapted the MASC from the long version of the MARS (Richardson & Suinn, 1972). In doing so, they adapted and shorted the number of questions so that it is more appropriate for younger children. There are 22 statements that students indicate how the scenario would make them feel on a four-point Likert scale: 1) not nervous; 2) a little nervous; 3) very nervous; or 4) extremely nervous (Chiu & Henry, 1990). Students receive scores ranging from 22 (no anxiety related to mathematics) to (highest level of anxiety related to mathematics). Due to lack of adequate mathematics anxiety scales for younger children, this scale was chosen because of its high correlation to the MARS scale ($r = .97$) and its high level of internal consistency reliability and construct validity (Beasley, et al., 2001; Chiu & Henry, 1972).

Procedures

Permission to carry out the study will be approved through the Oklahoma State University Institutional Review Board and the school district in which the participants are located. The researcher will meet with the principals and teachers from participating classrooms to discuss the details of the study and to send home consent forms for students' parents to complete (see Appendix C). Once consent is gathered, a date will be scheduled for graduate students to administer the math anxiety scale and math fact fluency probes.

Students will be given a seven-page packed which contains assent forms (Appendix D), demographic questionnaire (Appendix E), the MASC, a mixed math probe measuring accuracy, and timed tests in basic mathematical operations (i.e., addition, subtraction, multiplication, and division). The researcher will read the script verbatim (see Appendix G) and present each mathematics probe for 2 minutes. Once the time is up, the researcher will say, "Stop, and put your pencils down" and visually check to ensure no students continue to work. Probes will be counterbalanced to decrease effects of confounding variables (e.g., practice or fatigue). Graduate students will score all the probes using CBM scoring procedures (see Appendix A & B) and 30% of the probes will be scored independently a second time to reliability of scoring DCPM and errors.

Data Analysis

This study will utilize hierarchical multiple regression to examine the predictive relationship between math fact accuracy and math fact fluency with mathematics anxiety while controlling for demographic variables (Navarro & Foxcroft, 2018). This analysis was chosen because it is a type of multiple regression that can enter predictor variables at different times, or in different blocks, to determine how much variance each predictor variable (i.e., accuracy and fluency) explains in the continuous dependent variable (i.e., MASC scores). In this analysis, several regression models will be built by adding variables to the previous model. The purpose of this study is to examine whether added variables add improvement in the proportion of explained variance in mathematics anxiety.

To determine the fraction of variation in the outcome variable (i.e., mathematics anxiety) is predicted by addition of predictor variables, R^2 and ΔR^2 will be reported based on Model Summary and Model Comparison results (Navarro & Foxcroft, 2018). In addition to examining change in the explained variance, standardized coefficients (beta coefficients, β) will be examined to determine the how much the outcome variance is expected to increase or decreased when the predictor variables increase. This will add additional information about each individual predictor variable and its unique impact on the outcome variable. Standardized coefficients are being used because it allows to compare variables measured by different units of measurement. This will be represented in a regression equation to show the degree to which mathematics anxiety can be predicted by the predictor variables.

In hierarchical multiple regression, also sometimes referred to as hierarchical regression, the order in which variables are entered into blocks is determined by the researcher (Navarro & Foxcroft, 2018). This order in which variables are entered can be determined through theoretical, logical, or arbitrary reasoning (Navarro & Foxcroft, 2018). For the purpose of this study, demographics have been established as having a relationship with mathematics anxiety; for this reason, demographics will be entered into the first model to serve as a control. This allows for the researcher to see how much variance in math anxiety is accounted for by accuracy and fluency scores while controlling for demographics. The second model includes overall accuracy, and the third model included overall fluency rates. Fluency was determined to come after accuracy due to the order in which it occurs in Haring and Eaton's (1978) proposed stages of advanced learning.

Assumptions

The assumptions for hierarchical multiple regression are the same as multiple regression. Testing of assumptions will be completed during preliminary data screening (Navarro & Foxcroft, 2018). Assumptions for hierarchical multiple regression include a) linear relationship between predictor and outcome variables; b) no multicollinearity; c) values of the residuals are independent; d) homoscedasticity; and f) no significant outliers.

The first assumption of a linear relationship between predictor and outcome variables will be checked by visual inspection of the scatterplots or partial regression plots. For this study, Q-Q plot of residuals will be examined. This assumption would be consider met if the Q-Q plot displays that the residuals data points lie close to the diagonal line, displaying a linear relationship (Navarro & Foxcroft, 2018).

The second assumption of no multicollinearity will be used to ensure that the predictor variables are not too highly correlated with each other. To assess this, an analysis of Pearson correlation coefficient (r) and VIF scores will be used. This assumption has been met if correlations are below r=.7 and if VIF scores are below 10 (Navarro & Foxcroft, 2018).

The third assumption of independent residuals ensures the residuals are uncorrelated. This will be determined using the Durbin-Watson statistic. This statistic can vary from 0 to 4, and for this assumption to be met the Durbin-Watson value should be close to 2 (Navarro & Foxcroft, 2018).

The fourth assumption of homoscedasticity assumes that the variation in the residuals is similar to each point in the model. This will be examined through visual inspection of residual plots. The assumption has been met if the residuals appear random and do not take on a funnel shape (Navarro & Foxcroft, 2018).

The last assumption assumes there are no significant outliers influencing the model. This assumption will be tested using the Cook's Distance statistic to determine if the value is greater than one. If there are any values greater than one, then there is an outlier that may be influencing this studies model (Navarro & Foxcroft, 2018).

CHAPTER IV

RESULTS

The aim of this study was to expand upon current research examining the relationship between mathematics anxiety as it is related to a more sensitive measure of performance (i.e., fluency) in fourth and fifth grade students. This study utilizes hierarchical multiple regression to examine the predictive relationship between math fact accuracy and fluency with mathematics anxiety while controlling for demographic variables. The first block in the model includes gender and grade as demographic variables. These variables were controlled to determine whether accuracy and fluency would add significant explained variance to the predictive model for mathematics anxiety. The second block in the model includes the average accuracy of each subject across four separate math probes (i.e., addition to 18, subtraction from 18, multiplication to 81, and division from 81). The third block in the model includes average digits correct per minute as a measure of fluency across the different four math probes. Fluency was determined to come after accuracy due to the order in which it occurs in Haring and Eaton's (1978) proposed stages of advanced learning.

Research Questions

The research questions for this study are:

Research Question 1: Is there a statistically significant relationship between demographics, math fact error rates, and math fact fluency on math anxiety scores in fourth and fifth grade students?

Research Question 2: Is there a statistically significant contribution of demographic variables in predicting math anxiety in fourth and fifth grade students?

Research Question 3: Controlling for demographics, is there a statistically significant contribution of overall accuracy in predicting math anxiety in fourth and fifth grade students?

Research Question 4: Controlling for demographics and accuracy, is there a statistically significant contribution of overall fluency rate in predicting math anxiety in fourth and fifth grade students?

Hypotheses

The following are the research hypotheses for this study:

Hypothesis 1: There is a statistically significant predictive relationship between demographics, math fact accuracy, and math fact fluency in mathematics anxiety in fourth and fifth grade students.

Hypothesis 2: There is a statistically significant contribution of demographics in predicting math anxiety in fourth and fifth grade students.

Hypothesis 3: There is a statistically significant contribution of overall accuracy in predicting math anxiety in fourth and fifth grade students when controlling for demographics.

Hypothesis 4: There is a statistically significant contribution of overall fluency rates in predicting math anxiety in fourth and fifth grade students when controlling for demographics and overall accuracy.

Descriptive Statistics

The demographic data of the sample are provided in **Table 3.1**. This table provides information about the count of each sample characteristic measures and the percental of total. The sample includes 52.6% of 4^{th} graders (N = 101) and 47.4% of 5^{th} graders (N = 47.4%). Additionally, there were more males (N = 107, 55.7% of total) than females in this study (N = 85, 44.3% of total). The differences races in this study are represented below. The majority of participants were Caucasian (N = 95, 49.5% of total) while the following majority of indicated race is 'Prefer not to specify' (N = 35, 18.2% of total).

Table 3.1

Sample Characteristics

Demographic Variable	Sample Characteristic	Counts	Percentage of Total
Grade	4^{th} Grade	101	52.60%
	5^{th} Grade	91	47.40%
Gender	Male	107	55.70%
	Female	85	44.30%
Race	American Indian	15	7.80%

Demographic Variable	Sample Characteristic	Counts	Percentage of Total
	Asian	11	5.70%
	Black	4	2.10%
	Caucasian	95	49.50%
	Hispanic	10	5.20%
	Multiracial	10	6.20%
	Other	12	6.20%
	Prefer not to specify	35	18.20%

Descriptive statistics, including mean, standard deviation and range for the outcome variable and predictor variables in the study are presented below in Table 3.2. Mathematics anxiety was the outcome variable in this study was measures using the Mathematics Anxiety Scale for Children (MASC). Scores on the MASC can range from 22 (no anxiety related to mathematics) to 88 (highest level of anxiety related to mathematics). In this study, scores ranged from 22 (no anxiety related to mathematics) to 73 (severe anxiety related to mathematics) with a mean of 38.4 (low levels of anxiety related to mathematics) and a standard deviation of 10.6.

Table 3.2

Predictor and Outcome Descriptive Statistics

	Mathematics Anxiety	Accuracy	Average DCPM
N	192	192	192
Mean	38.40	0.92	21.80
Standard deviation	10.60	0.12	10.70
Minimum	22.00	0.25	3.75

	Mathematics Anxiety	Accuracy	Average DCPM
Maximum	73.00	1.00	64.30

Additional descriptive statistics presented below in Table 3.3. This table displays the mean, standard deviation, and range for each demographic variable that were controlled for in this study (i.e., grade and gender) in relation to predictor and outcome variables (i.e., accuracy, average DCPM, and mathematics anxiety). In fourth grade, males and female scored the same on measures of accuracy (0.91), while males had a larger range of scores (0.75 SD). In fifth grade, males (0.95) performed slightly higher on measures of accuracy when compared to females (0.92). However, fourth and fifth grade males performed higher on measures of fluency (4^{th} = 18.50 DCPM, 5^{th} = 28.08 DCPM) compared to females in their grade (4^{th} = 15.91 DCPM, 25.19 DCPM). Males also reported lower levels of mathematics anxiety in fourth grade (35.31, low anxiety related to mathematics) and fifth grade (38.37, low anxiety related to mathematics) compared to compared to females in their same grades (4^{th} grade = 37.92, low anxiety related to mathematics; 5^{th} grade = 43.08, moderate anxiety related to mathematics).

Table 3.3

Sample Characteristics Descriptive Statistics

	Grade	Gender	N	Mean	SD	Range
Accuracy	4^{th}	Male	64	0.91	0.14	0.75
		Female	37	0.91	0.12	0.47
	5^{th}	Male	43	0.95	0.07	0.28
		Female	48	0.92	0.13	0.50

	Grade	Gender	N	Mean	SD	Range
Average DCPM	4th	Male	64	18.50	9.37	41.25
		Female	37	15.91	5.99	31.00
	5th	Male	43	28.08	12.01	55.75
		Female	48	25.19	10.25	50.00
Mathematics Anxiety	4th	Male	64	35.31	10.33	38.00
		Female	37	37.92	8.85	37.00
	5th	Male	43	38.37	9.39	36.00
		Female	48	43.08	11.73	51.00

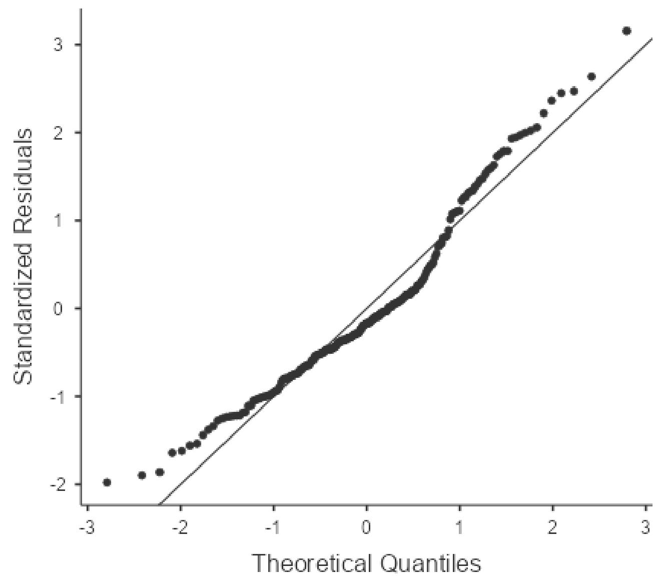
Assumption Testing

Prior to conducing a hierarchical multiple regression, the relevant assumptions of this this statistical analysis were tested. Firstly, a sample size of 197 was deemed adequate given three predictor variables included in the analysis (Navarro & Foxcroft, 2018). The assumptions tested include a) linearity; b) uncorrelated predictors; c) residuals are independent of each other; d) homogeneity of variance; e) no significant outliers.

The first assumption examined in this hierarchical multiple regression analysis was the linear relationship between predictor and outcome variables. This assumption can be tested through visual inspection of scatterplots or partial regression plots. Figure 1.1 displays the partial regression plots through the Q-Q plot of residuals. Based on the figure below displaying a linear relationship, the first assumption has been met.

Figure 1.1

Q-Q Plot of Residuals



The second assumption in hierarchical multiple regression assumes that there is no multicollinearity in the data; meaning, the predictor variables are not highly correlated with each other. This assumption was checked in two ways: 1) examining the correlations between predictor variables; and 2) examining the variance inflation factor (VIF) which indicated the degree in which variances are increased due to multicollinearity. This assumption has been met if correlations are below r=.7 and if VIF scores are below 10.

Table 4.1

Correlation Matrix

	Grade	**Gender**	**Accuracy**	**Average DCPM**
Grade	—	—	—	—
Gender	0.162*	—	—	—
Accuracy	0.10	- 0.04	—	—

Average DCPM	0.42**	- 0.06	0.45***	—
Mathematics Anxiety	0.22**	0.20**	- 0.19**	- 0.16*

Note. * p < .05, ** p < .01. *** p <.001

The information presented in Table 4.3 indicated there are not concerning highly correlated variables. The highest correlation between predictor variables is between accuracy and average digits correct per minute (DCPM), r=0.446. With all correlations less than r=.7 this indicates there are no concerning correlations between predictor variables. Table 4.4 displays the results for Collinearity Statistics, reporting the highest VIF as 1.54. Based on these results, there is no violation of the assumption of no multicollinearity.

Table 4.2

Collinearity Statistics

	VIF	Tolerance
Accuracy	1.26	0.79
Average DCPM	1.54	0.65

The third assumption tested was the assumption the values of the residuals are independent. This ensures that our observations are independent from one another and are not too highly correlated. This assumption was tested using the Durbin-Watson statistic. The Durbin-Watson statistic, as displayed in Table 4.3, shows that this assumption has been met, as the obtained value was close to 2 (Durbin-Watson = 2.07).

Table 4.3

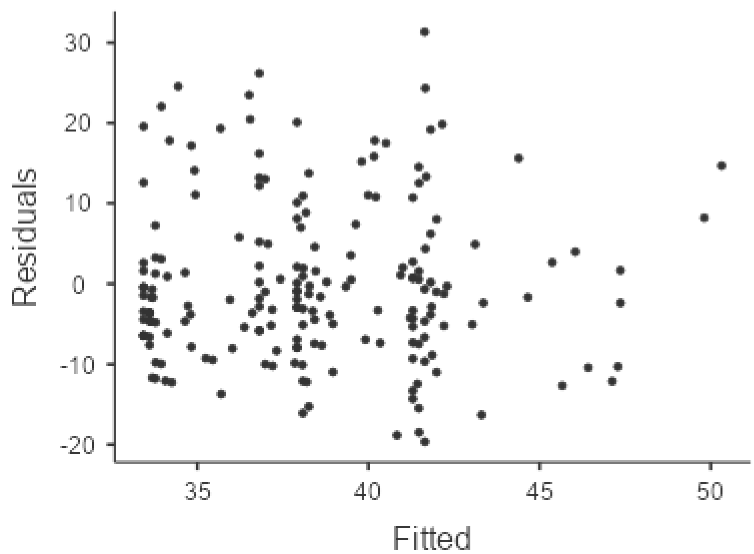
Durbin-Watson Test

Autocorrelation	Durbin-Watson Statistic	p value
-0.0408	2.07	0.70

The fourth assumption of homoscedasticity assumes the variation in the residuals is similar at each point of the model. This was examined through visual inspection of residual plots as seen in Figure 1.2. This assumption has been met because the residuals appear more random and do not take on a funnel shape.

Figure 1.2

Residual Plots



The final assumption is there are no influential cases (outliers) biasing the model. This assumption is tested using Cook's Distance statistic to determine if there are any values greater than 1 there are likely to be significant outliers indicating this assumption has been violated. The Cook's Distance statistic, as displayed in Table 4.4, shows this assumption has been met, as the max value was less than 1 (Cooks Distance = 0.0925).

Table 4.4

Cook's Distance

			Range	
Mean	**Median**	**SD**	**Min**	**Max**
0.00530	0.00162	0.00984	3.35e-7	0.093

Hierarchical Multiple Regression Results

The primary research question for this study sought gain a better understanding of the relationship between mathematics performance and mathematics anxiety using a more sensitive measure of performance (i.e., fluency). Additionally, this study aimed to add to the current literature regarding the existence of a relationship between accuracy as a measure of performance with mathematics anxiety while controlling for demographic variables. For data analysis, this study used hierarchical multiple regression and predictor variables were entered in three blocks which resulted in three different models. The three different models for this study are found in Table 4.5. Results for each model are reported separately below to present the contribution each predictor variable had on mathematics anxiety. The results of each of these models can be seen below in Tables 4.6 - 4.8.

Table 4.5

Blocks for Hierarchical Multiple Regression

Block	Predictor Variable	Criterion Variable
1	Gender + grade	= math anxiety
2	Gender + grade + fact accuracy	= math anxiety
3	Gender + grade + fact accuracy + fact fluency	= math anxiety

Overall Model

To approach the first research question "Is there a statistically significant relationship between demographics, math fact error rates, and math fact fluency on math anxiety scores in fourth and fifth grade students?", a linear regression analysis was conducted to evaluate the prediction between all predictor variables combined and the outcome variable. For the overall regression analysis, the predictor variables were all entered at the same time and analyzed. Results revealed demographic variables, accuracy, and fluency explained 15% of variation in mathematics anxiety, F = (4, 187) = 8.30, $p < .001$. Therefore, the overall regression was statistically significant ($R^2 = 0.15$).

Table 4.6

Model Summary

				Overall Model Test			
Model	**R**	**R²**	**Adjusted R²**	**F**	**df1**	**df2**	**p**
1	0.28	0.08	0.07	7.74	2	189	< .001***
2	0.35	0.12	0.11	8.48	3	188	< .001***
3	0.39	0.15	0.13	8.30	4	187	< .001***

Note. 1 Predictors: Gender and grade; 2 predictors: gender, grade, and accuracy; 3 predictors: gender, grade, accuracy, and fact fluency.

Block One

To approach the research question "Is there a statistically significant contribution of demographic variables in predicting math anxiety in fourth and fifth grade students?", a hierarchical multiple regression analysis was conducted to evaluate the prediction of mathematics anxiety from demographic variables. For the first block analysis, the predictor variables gender and grade were analyzed. The first block of the hierarchical multiple regression analysis revealed that demographic variables (i.e., gender and grade) contributed significantly to the regression model, F (2, 189) = 7.74, $p < .05$ and accounted for 8.00% of the variation in mathematics anxiety as indicated by R^2 (Table 4.6). The results for each individual predictor within the regression model are shown in Table 4.8. Gender is a significant ($\beta = 0.14$, $p < .05$) unique predictor of mathematics anxiety and so is grade ($\beta = .30$, $p < .001$). Therefore, demographic variables included in this model do play a significant role in predicting mathematics anxiety.

Table 4.7

Model Comparisons

Comparison							
Model		**Model**	**ΔR²**	**F**	**df1**	**df2**	**p**
1	-	2	0.04	9.27	1	188	0.003**
2	-	3	0.03	6.97	1	187	0.009**

Note. * p < .05, ** p < .01. *** p <.001

Block Two

The second model introduced math fact accuracy across multiple probes to determine if there is any additional explained variance in predicting mathematics anxiety. This model addresses the second research question, "Controlling for demographics, is there a statistically significant contribution of overall accuracy in predicting math anxiety in fourth and fifth grade students?". Introducing accuracy to the second model of the hierarchical multiple regression revealed when controlling for demographic variables, accuracy explained an additional 4.00% of variation in mathematics anxiety. That increase is associated with a significant R^2 change, $F = (1,188) = 9.27$, $p < .001$ as shown below in **Table 4.7**. However, accuracy is not a significant ($\beta = -0.11$, $p > .05$) unique predictor of mathematics anxiety. Therefore, adding accuracy to the model increased the overall model's predictive capacity at predicting overall mathematics anxiety; however, as a predictor variable it is not a significant unique predictor of the overall model.

Table 4.8

Overall Model Coefficients

Predictor	Estimate	SE	t	p	Stand. Estimate
Intercept	48.59	5.6245	8.64	< .001***	
Gender	2.90	1.4651	1.98	0.049**	0.14
Grade	6.34	1.6121	3.93	< .001***	0.30
Accuracy	-10.48	6.5624	-1.60	0.112	-0.12
Average DCPM	-0.22	0.0824	-2.64	0.009**	-0.22

Note. p < .05, * p < .01. ** p <.001***

Block Three

The third block introduced math fact fluency across multiple probes to determine if there is any additional explained variance in predicting mathematics anxiety. This block addresses the third research question, "Controlling for demographics and accuracy, is there a statistically significant contribution of overall fluency rate in predicting math anxiety in fourth and fifth grade students?". Introducing fluency to the third block of the hierarchical multiple regression revealed when controlling for demographic variables and accuracy, fluency explained an additional 3.00% of variation in mathematics anxiety. Block 3 demonstrates that combined the predictor variables explain a total of 15.00% of variance in the model. That increase from Block 2 is associated with a significant R^2

change, $F = (1,187) = 6.97$, $p < .05$ as shown below in Table 4.7. Additionally, fluency is a significant ($\beta = -0.22$, $p < .01$) unique predictor of mathematics anxiety (Table 4.8). Therefore, adding fluency to the model increased the overall model's predictive capacity at predicting overall mathematics anxiety. Also, beta coefficients indicate when controlling for the impact of all other variables, fluency maintained significant unique contribution towards mathematics anxiety.

Summary

Overall, this hierarchical analysis included three separate blocks of predictor variables that as a whole contributed a significant amount of variance to the predictor of mathematics anxiety, as indicated by the significant R^2 for the overall model. Block 1 (demographics) contributed a significant amount of variance to the prediction of mathematics anxiety and each predictor variable included in this block (i.e., gender and grade) were identified as unique predictors. Block 2 (accuracy) did contribute a significant amount of variance to the prediction of mathematics anxiety, as indicated by R^2 and ΔR^2. However, accuracy was not identified as a unique predictor of mathematics anxiety. Block 3 (fluency) contributed a significant amount of variance to mathematics anxiety as an indicated by significant R^2 and ΔR^2. Additionally, fluency was identified as a significant unique predictor of mathematics anxiety as indicated by significant beta coefficients. Therefore, the regression equation for this study is $\hat{Y} = 0.14X1 + 0.30X2 - 0.22X4$.. The results of each of the null hypothesis are shown below in Table 4.9.

Table 4.9

Summary of Tested Hypotheses

Hypothesis	Statement	R^2	ΔR^2	β	Accepted (Yes/No)
H_1	There is a statistically significant predictive relationship between demographics, math fact accuracy, and math fact fluency in mathematics anxiety in fourth and fifth grade students.	15.00%	-	-	Yes
H_2	There is a statistically significant contribution of demographics in predicting math anxiety in fourth and fifth grade students.	8.00%	-	Gender, 0.14 Grade, 0.30	Yes
H_3	There is a statistically significant contribution of overall accuracy in predicting math anxiety in fourth and fifth grade students when controlling for demographics.	12.00%	4.34%	-0.12	Yes
H_4	There is a statistically significant contribution of overall fluency rates in predicting math anxiety in fourth and fifth grade students when controlling for demographics and overall accuracy.	15.00%	3.16%	-0.22	Yes

CHAPTER V

DISCUSSION AND IMPLICATIONS

Mathematics anxiety is the most common form of academic anxiety that occurs in education (Blazer, 2011). Math anxiety can be described as a state of discomfort during math tasks and can include worry, frustration, fear, and dislike. This discomfort commonly leads to avoidance of math tasks, coursework, types of college majors, and careers in STEM (Hackett, 1985; Johnston-Wilder, et al., 2014; Lyons, et al., 2012; Pizzie & Kraemer, 2017). This may limit students who lack the confidence and skills to continue education with mathematics and science in an era where STEM occupations are projected to grow 10.5% in the next 8 years compared to 3.7% growth in all other occupations (Cabell, et al., 2021).

It is important for educators, interventionists, curriculum coordinators, and school psychologist to understand the causes and maintaining variables of math anxiety so we can successfully support children in academic skill development. The aim of this study was to expand upon research examining the relationship between math performance as it is related to math anxiety. Performance of skills in education, and mathematics anxiety research, is typically determined by broad, accuracy-based measurements. This study added a more sensitive measure of performance (i.e., fluency) to a hierarchical multiple regression model to determine if fluency adds significant unique variance in predicting mathematics anxiety.

This study found that combined, predictor variables contributed a statistically significant amount of variance to the prediction of mathematics anxiety. More specifically, the hierarchical regression analysis revealed that each block added to the model contributed significantly to the change in explained variance. However, although statistically significant the model has low R^2 values.

Falk and Miller (1992) recommended that R^2 values should be equal to or greater than 0.10 in order for the variance explained of a particular model to be deemed adequate. According to Cohen (1992), in social sciences, R^2 value of .12 or below indicate low, between .13 to .25 values indicate medium, .26 or above and above values indicate high effect size. Using the criteria above, models 1 and 2 have a low and model 3 has a medium effect size. This indicates although there are significant values, the overall model when fluency is added, explains approximately 15% of variation in predicting mathematics anxiety indicating a medium effect. It also should be noted that while holding other variables constant, fluency ($\beta = -0.22$, $p < .01$) maintained a significant unique contribution towards mathematics anxiety while accuracy ($\beta = -0.11$, $p > .05$) which did not. The provides useful information, as it informs us that although fluency alone does not explain a large portion of the variability in math anxiety, the B value of -.22 means decrease in fluency rates by 1 standard deviation will produce a corresponding .22 increase in math anxiety. Therefore, fluency as a performance measure may be more useful skill to assess and increase than accuracy when trying to prevent and/or address mathematics anxiety.

There are common misconceptions about the causes and maintaining variables of mathematics anxiety. Teachers may stray away from timed practice or timed test for concern that it may increase math anxiety. Additionally, there is common focus of teaching conceptual knowledge, while overlooking the importance of gaining mastery of fundamental skills, such as basic math facts. In schools, educators may interpret student's disengagement of mathematics activities or saying they dislike math as an innate personality trait. However, a student may have developed a negative attitude toward math due to a cycle of poor performance, worry, avoidance, and continued poor performance.

Supporting students' math learning is complex and the National Mathematics Advisory (NMAP) indicates it should include: (a) systematic, explicit instruction; (b) opportunities to practice; (c) enhancement of conceptual understanding; and (d) assessment of progress (NMAP, 2008). Students, particularly those who are low achieving, do not naturally develop automaticity of math facts without dedicated practice and instruction (Woodward, 2006). When students do not master basic math skills and continue onto more complex tasks, they may start to experience anxiety around math tasks because they are having to use more of their cognitive load to complete this work and are not experiencing increased success with their performance. Increased fluency and automaticity on basic skills helps students reduce their cognitive load for more complex tasks by using a more efficient strategies (i.e., direct retrieval) to complete a multi-step problem. When thinking of this in practice, it may intuitively make sense.

For example, when breaking down the steps of a long division problem, a student needs to use a combination of addition, subtraction, multiplication, and division. A lack of automaticity makes novel tasks nearly impossible for students to complete in a timely manner. Research shows that achieving fast, accurate, and effortless recall of computation facts, allows students to focus more energy on more complex aspects of a math problem (NAMP, 2008) and learn higher-level math skills with less effort (Pellegrino & Goldman, 1987; Tolar, et al., 2009). This study adds to the current literature and supports the notion that higher rates of fluency are associated with lower levels of mathematics anxiety.

In mathematics anxiety research, broad measures of academic achievement (e.g., test scores or percent accurate) are commonly used to explore the relationship between performance and anxiety. The findings from this study support earlier research suggesting the relationship between mathematics performance and mathematics anxiety is complex. This relationship may be better understood by assessing a more sensitive measure of performance (i.e., fluency) which leads to a more precise understanding of the functional relationship between mathematics anxiety and mathematics performance.

Implications

Understanding what influences math anxiety important implications for a majority of school personnel who are tasked with providing services to support and remediate math skill development in children. Educators often approach math by teaching concepts than procedures. However, dedicating a few minutes of daily math fact fluency practice would help build foundational skills that may allow students to master increasingly complex content easier and alleviate frustrations. Development of conceptual understanding, strategies, and automaticity is not linear and develops reciprocally. Students taught with an integrated approach generally perform better on measures of fluency and can more flexibly apply learned strategies to increasingly complex problems (Rittle-Johnson, et al., 2015)

For academic interventionists, it provides support for assessing and targeting math fact fluency when a student is displaying math avoidance and/or difficulties with more complex math concepts. Students who improve their math skills report high self-efficacy and confidence in math (Woodward, 2006). Similarly, for school psychologists it provides information about influences on academic skills which improves effective collaboration and consultation with other school personnel. School psychologists should use assessment data related to math performance to help inform evidence-based individual and systematic approaches for math skill development in children.

Lastly, mathematics curricula in the United States have a lack of emphasis placed on sufficient practice and mastery of basic fact combinations (Doabler & Fine, 2012; NMAP, 2009). For curriculum coordinators, it is important to determine evidence-based mathematics curriculum that teaches concepts, strategies, *and* automaticity so these skills can mutually support and further the development of the other (Rittle-Johnson, et al.,2015).

Limitations of the Study

This study utilizes hierarchical multiple regression to examine the predictive relationship between math fact accuracy and fluency with mathematics anxiety while controlling for demographic variables. A limitation to this study is the research design itself. Hierarchical multiple regression is a correlational predictive design. These types of designs are used to determine the direction and magnitude of the relationship between variables, or the “association”. Therefore, this study can infer about the magnitude of the relationship but cannot infer causality and explain any causes of mathematics anxiety.

Another limitation of this study is the sample. The sample for this study were students in a suburb, of a southern state, within the same school district. The sample is not representative of the U.S. population and therefore without further information findings may not generalize to other populations.

Also, there is a limitation of the nature of the measures administered. Self-report measures are inherently flawed and pose validity problems. Students may exaggerate symptoms, under-report the severity of symptoms, and young students may have a difficult time accurately rating their feelings on a scale. Additionally, for measures of accuracy this study used average percent correct of completed problems on a mixed math probe which include four separate skills (i.e., addition, subtraction, multiplication, and division). Accuracy can be measured in numerous ways, potentially resulting in different findings on accuracy-based performance measures.

Lastly, in a multiple regression analysis there is the concern for omitted-variable bias. This occurs when a statistical model leaves out relevant variables to ensure the predictive model is as accurate as possible. Additional variables that may have been important and significant to the model include but are not limited to prior achievement, social and economic status, teachers’ comfortability with teacher math concepts, and parents’ attitudes towards math.

Recommendations for Future Research

As mentioned above, this study has limitations that would lend itself well to future research. Overall, the predictors in this model only accounted for 15% of variance in the overall model. Including relevant variables that may be significant could increase the accuracy and overall predictive compacity of the model.

Additionally, this predictive correlation design does not provide information on the causality between the predictor and outcome variables. There is limited research examining and comparing therapeutic and skill intervention daily. This type of information could lead to understanding the causal relationship between performance and mathematics anxiety. Additionally, it would increase the evidence-base for which type of intervention needed (therapeutic or skill based) to prevent and decrease mathematics anxiety, while also increasing performance.

Conclusion

This study aims to provide more information regarding the predictive relationship between mathematics anxiety and mathematics performance using a more sensitive measure of performance, fluency. Knowledge and mastery of skill in education, and mathematics anxiety research, is typically determined by accuracy-based measurements. However, more advanced stages of learning happen beyond acquisition of skill and are needed to gain mastery of a skill (Rivera & Bryant, 1992). Haring and Eaton's (1978) proposed theory of learning, the instructional hierarchy, provides a useful framework for using a more sensitive measure (i.e., fluency) to measure mathematics performance. This leads to a more precise understanding of the functional relationship between mathematics anxiety and mathematics performance.

In this study, fourth and fifth grade students completed a seven-page packed which included a demographic questionnaire, the Mathematics Anxiety Scale for Children (MASC), a mixed math probe measuring accuracy, timed tests in basic mathematical operations (i.e., addition, subtraction, multiplication, and division). Findings from the hierarchical multiple regression suggests that in addition to demographic information and accuracy-based measures, adding fluency to the model increased the overall model's predictive capacity at predicting overall mathematics anxiety. Additionally, when controlling for the impact of all other variables, fluency maintained a significant unique contribution towards mathematics anxiety. Therefore, ensuring students have automaticity of basic math facts and extending students learning beyond accuracy may provide useful in providing services to support and/or remediate math skill development in children.

REFERENCES

Anderson, T (2nd). (2008). *The theory of practice and online learning.* AU Press: Athabasca University.

Akinsola, M. K., Tella, A., & Tella, A. (2007). Correlates of academic procrastination and mathematics achievement of university undergraduate students. *Eurasia Journal of Mathematics, Science & Technology Education*, *3*(4), 363-370.

Archer, A. L., & Hughes, C. A. (2010). Explicit instruction: Effective and efficient teaching. New York, NY: Guilford

Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General, 130,* 224-237. https://doi.org/10.1037/0096-3445.130.2.224

Ashcraft, M., & Moore, A. (2009). Mathematics Anxiety and the Affective Drop in Performance. *Journal of Psychoeducational Assessment, 27(3*), 197-205. https://doi.org/10.1177/0734282908330580

Ashcraft, M. H. & Ridley, K. S. (2005). Math anxiety and its cognitive consequences: A tutorial review. In J. I. D. Campbell (Ed.), Handbook of Mathematical Cognition (pp. 315–30). New York: Psychology Press.

Ahmed, W. (2018). Developmental trajectories of math anxiety during adolescence: Associations with STEM career choice. *Journal of Adolescence, 67,* 158. https://doi.org/10.1016/j.adolescence.2018.06.010

Baddeley, A. D., Hitch, G., & Bower, G. H. (1974). The psychology of learning and motivation.

Beasley, T., Long, J., & Natali, M. (2001). A Confirmatory Factor Analysis of the Mathematics Anxiety Scale for Children. Measurement and Evaluation in Counseling and Development, 34(1), 14-26. https://doi.org/10.1080/07481756.2001.12069019

Beck, R. (1979). Report for the Office of Education joint dissemination review panel. *Great Falls, Montana: Precision Teaching Project*.

Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences*, *107*(5), 1860-1863.https://doi.org/10.1073/pnas.0910967107

Binder, C. (2003). Doesn't everybody need fluency? Performance Improvement, 42(3), 14-20. https://doi.org/10.1002/pfi.4930420304

Binder, C., & Sweeney, L. (2002). Building fluent performance in a customer call center. Performance Improvement, 41(2), 29-37.

Blazer, C. (2011). Strategies for Reducing Math Anxiety. Information Capsule. Volume 1102. *Research Services, Miami-Dade County Public Schools*.

Brown, S., & Bennett, E. (2002). The role of practice and automaticity in temporal and nontemporal dual-task performance. *Psychological Research, 66*(1), 80-89. https://doi.org/10.1007/s004260100076

Bucklin, B., Dickinson, A., & Brethower, D. (2000). A comparison of the effects of fluency training and accuracy training on application and retention. *Performance Improvement Quarterly, 13(3),* 140-163. https://doi.org/10.1111/j.1937-8327.2000.tb00180.x

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental neuropsychology*, *19*(3), 273-293.

Burns, M. (1998). Math: Facing an American phobia. Sausalito, CA: Math Solutions Publications.

Burns, M.K., Codding, R.S., Boice, C.H., & Lukito, G. (2010). Meta-analysis of acquisition and fluency math interventions with instructional frustration level skills: Evidence for a skill-by-treatment interaction. School Psychology Review, 39(1), 69-83. https://doi.org/10.1080/02796015.2010.1208779

Casad, B., Hale, P., & Wachs, F. (2015). Parent-child math anxiety and math-gender stereotypes predict adolescents' math education outcomes. *Frontiers in Psychology, 6,* 1597. https://doi.org/10.3389/fpsyg.2015.01597

Chiu, L.-h., & Henry, L. L. (1990). Development and validation of the Mathematics Anxiety Scale for Children. *Measurement and Evaluation in Counseling and Development, 23*(3), 121–127.

Codding, R. S., Chan-Iannetta, L., George, S., Ferreira, K., & Volpe, R. (2011). Early number skills: Examining the effects of class-wide interventions on kindergarten performance. *School Psychology Quarterly*, *26*(1), 85.

Codding, R. S., Hilt-Panahon, A., Panahon, C. J., & Benson, J. L. (2009). Addressing mathematics computation problems: A review of simple and moderate intensity interventions. *Education and Treatment of Children*, 279-312.

Codding, R. S., Shiyko, M., Russo, M., Birch, S., Fanning, E., & Jaspen, D. (2007). Comparing mathematics interventions: Does initial level of fluency predict intervention effectiveness?. *Journal of School Psychology*, *45*(6), 603-617.

Codding, R., Volpe, R., & Poncy, B. (2016). *Effective Math Interventions: A Guide to Improving Whole-Number Knowledge*. New York: Guilford Publications.

Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112(1), 155.

Conway, A., Kane, R., Bunting, A., Hambrick, M., Wilhelm, J., & Engle, F. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review, 12(5),* 769-786. https://doi.org/10.3758/BF03196772

Deno, S. L., & Mirkin, P. (1977). *Data-based program modification: A manual*. Leadership Training Institute/Special Education, University of Minnesota.

Doabler, C., & Fien, H. (2013). Explicit mathematics instruction: What teachers can do for teaching students with mathematics difficulties. *Intervention in School and Clinic, 48*(5), 276-285. https://doi.org/10.1177/1053451212473151

Dowker, A., Cheriton, O., Horton, R., & Mark, W. (2019). Relationships between attitudes and performance in young children's mathematics. Educational Studies in Mathematics, 100(3), 211-230.

Eccles, J. S., Jacobs, J. E.,& Harold, R. (1990).Gender role stereotypes, expectancy effects, and parents' socialization of gender differences. *Journal of Social Issues*, *46,* 183–201. https://doi.org/10.1111/j.1540-4560.1990.tb01929.x

Falk, R. F., & Miller, N. B. (1992). A primer for soft modeling. *University of Akron Press*.

Fayer, S., Lacey, A., & Watson, A. (2017). STEM occupations: Past, present, and future. Spotlight on statistics. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics.

Fennema, E., & Sherman, J. A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments

designed to measure attitudes toward the learning of mathematics by females and males. *Catalog of Selected Documents in Psychology,* 6, 1–32.

Furner, J., & Berman, B. (2003). Review of Research: Math Anxiety: Overcoming a Major Obstacle to the Improvement of Student Math Performance. *Childhood Education, 79(3),* 170-174.

Gersten, R. (1988). Explicit instruction in reading comprehension strategies. *European Journal of Psychology of Education, 3*(Supplement 1), 239.

Gersten, R., Beckmann, S., Clarke, B., Foegen, A., Marsh, L., Star, J. R., & Witzel, B. (2009). Assisting Students Struggling with Mathematics: Response to Intervention (RtI) for Elementary and Middle Schools. NCEE 2009-4060. *What Works Clearinghouse*.

Gersten, R., Jordan, N., & Flojo, J. R. (2005) Early identification and interventions for students with mathematics difficulties. *Journal of Learning Disabilities,* 38(4), 293-304.

Gettinger, M. (1995) Best Practices for increasing academic learning time. In A. Thomas & J. Grimes (Eds.) *Best practices in school psychology*, 3 (pp.943-954) Washington, DC: National Association of School Psychologists.

Glass Jr, J. C., & Kilpatrick, B. B. (1998). Gender comparisons of baby boomers and financial preparation for retirement. *Educational Gerontology: An International Quarterly*, *24*(8), 719-745.

Glover, J. A., Ronning, R. R., & Bruning. (1990). *Cognitive Psychology for Teachers.* Macmillan Pub Co.

Grays, S. D., Rhymer, K. N., & Swartzmiller, Melissa D. (2017). Moderating Effects of Mathematics Anxiety on the Effectiveness of Explicit Timing. *Journal of Behavioral Education, 26*(2), 188-200.

Grigg, W., Donahue, P., & Dion, G. (2007). *The nation's report card: 12th-Grade reading and mathematics 2005* (NCES 2007-468). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Gunderson, E., Ramirez, G., Levine, S, & Beilock, S. (2012). The role of parents and teachers in the development of gender-related math attitudes*.* *Sex Roles 66*(3-4),153–166. https://doi.org10.1007/s11199-011-9996-2

Hackett, G. (1985). Role of mathematics self-efficacy in the choice of math related majors of college women and men: A path analysis. *Journal of Counseling Psychology, 32(1),* 47-56.

Haring, N. G., & Eaton, M. D. (1978). Systematic instructional technology: An instructional hierarchy. In N. G. Haring, T. C. Lovitt, M. D. Eaton, & C. L. Hansen (Eds.), *The fourth R: Research in the classroom* (pp. 23–40). Columbus, OH: Merrill.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for research in mathematics education*, 33-46.

Isaacs, A. C., & Carroll, W. M. (1999). Strategies for basic-facts instruction. *Teaching Children Mathematics, 5*(9), 508–515.

Ischinger, B. (2008). Education at a glance 2008: OECD indicators. *Paris: Organization For Economic Co-operation and Development*.

Jacobs, J. E. (2005). Twenty-five years of research on gender and ethnic differences in math and science career choices: what have we learned? *New Dir. Child Adolesc. Dev.* 110, 85–94. https://doi.org/10.1002/cd.151

Jerald, C. D. (2008). Benchmarking for Success: Ensuring US Students Receive a World-Class Education. National Governors Association.

Johnson, K., & Layng, T. (1992). Breaking the structuralist barrier: Literacy and numeracy with fluency. *The American Psychologist, 47(11),* 1475.

Johnston-Wilder, S., Brindley, J., & Dent, P. (2014). A survey of mathematics anxiety and mathematical resilience among existing apprentices. *London: The Gatsby Foundation*.

Karp, K. S. (1991). Elementary school teachers' attitudes toward mathematics: The impact on students' autonomous learning skills. *School Science and Mathematics, 91(6),* 265–270.

Kelley, B., Hosp, J., & Howell, K. (2008). Curriculum-Based Evaluation and Math: An Overview. Assessment for Effective Intervention, 33(4), 250-256.

Kroesbergen, E., Johannes, V.H. (2003). Mathematics interventions for children with special educational needs: A meta-analysis. *Remedial and Special Education,* 24(2), 97-114.

Lyons IM, Beilock SL (2012) When Math Hurts: Math Anxiety Predicts Pain Network Activation in Anticipation of Doing Math. PLOS ONE 7(10): e48076. https://doi.org/10.1371/journal.pone.0048076

Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education, 30(5),* 520-540.

Ma, X., & Xu, J. (2004). Determining the causal ordering between attitude toward mathematics and achievement in mathematics. *American Journal of Education, 110(3),* 256-280.

Mack, J., & Walsh, B. (2013). Mathematics and science combinations NSW HSC 2001-2011 by gender. *Technical paper*.

Maloney, E. A., Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2015). Intergenerational effects of parents' math anxiety on children's math achievement and anxiety. *Psychological Science*, *26*(9), 1480-1488. https://doi.org/10.1177/0956797615592630

Marin, L. M., & Halpern, D. F. (2011). Pedagogy for developing critical thinking in adolescents: explicit instruction produces greatest gains. *Thinking Skills and Creativity 6,* 1-13.

Marsh, H. W., & Scalas, L. F. (2011). Self-concept in learning: Reciprocal effects model between academic self-concept and academic achievement. *Social and Emotional Aspects of Learning,* 191-198.

Martens, B. K., Lochner, D. G., Kelly, S. Q. (1992). The effects of variable-interval reinforcement on academic engagement: A demonstration of matching theory. *Journal of Applied Behavior Analysis, 25,* 143-151.

Menon, V. (2010). Developmental cognitive neuroscience of arithmetic: implications for learning and education. *ZDM*, 42(6), 515-525.

Methe, S., Kilgus, S., Neiman, C., & Riley-Tillman, T. C. (2012). Meta-analysis of interventions for basic mathematics computation in single-case research. *Journal of Behavioral Education, 21,* 230-253.

Miller, A. D., Hall, S. W., & Heward, W. L. (1995). Effects of sequential 1-minute time trials with and without inter-trial feedback and self-correction on general and special education students' fluency with math facts. *Journal of Behavioral Education*, *5*(3), 319-345.

Moors, A., & De Houwer, J. (2006). Automaticity: A theoretical and conceptual analysis. *Psychological Bulletin, 132*(2), 297-326.

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics.* National Governors Association Center for Best Practices, Council of Chief State School Officers, Washington D.C. http://www.corestandards.org/Math/

National Mathematics Advisory Panel. (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel.* Washington, DC: U.S. Department of Education. https://www2.ed.gov/about/bdscomm/list/mathpanel/report/final-report.pdf

National Research Council. (1989). Everybody counts: A report to the nation on the future of mathematics education. National Academies Press.

National Science Board. 2007. *A national action plan for addressing the critical needs for U.S. science, technology, engineering, and mathematics Education System*. Washington, DC: National Science Foundation Press.

Navarro, D., Foxcroft, R. (2018). Learning statistics with jamovi: a tutorial for psychology students and other beginners. *Danielle J. Navarro and David R. Foxcroft.*

OECD, P. (2013). Results: Ready to Learn (Volume III): Students' Engagement, Drive and Self-Beliefs.

Oklahoma State Department of Education (2016). *Oklahoma Academic Standards for Mathematics*. https://sde.ok.gov/sites/ok.gov.sde/files/documents/files/OAS-Math-Final%20Version_3.pdf

Okoiye, O., Okenzie, N., Nlemadim, M. (2017). Impact of academic procrastination and study habit on expressed mathematics anxiety of junior secondary students in Esan South-East Edo State Nigeria. *Br J Psychol Res 5(1),* 32-40.

Onwuegbuzie, A. (2004). Academic procrastination and statistics anxiety. *Assessment & Education in Higher Education, 29(1),* 3-19. https://doi.org/10.1080/0260293042000160384

Papousek, I., Ruggeri, K., Macher, D., Paechter, M., Heene, M., Weiss, E., Schulter, G., Freudenthaler, H. (2012). Psychometric Evaluation and Experimental Validation of the Statistics Anxiety Rating Scale. *Journal of Personality Assessment, 94(1)*, 82-91. https://doi.org/10.1080/00223891.2011.627959

Pellegrino, J. W., & Goldman, S. R. (1987). Information processing and elementary mathematics. *Journal of Learning Disabilities, 20*(1), 23-32, 57.

Perie, M., Grigg, W., & Dion, G. (2005). The Nation's Report Card [TM]: Mathematics, 2005. NCES 2006-453. National Center for Education Statistics.

Pew Research Center. (2008) Pew Research Center: Numbers, Facts, and Trends Shaping Your World . United States. [Archived Web Site] Retrieved from the Library of Congress, https://www.loc.gov/item/lcwaN0002821/.

Phillips, G. W. (2009). *The second derivative: International benchmarks in mathematics for U.S. states and school districts.* Washington, DC: American Institutes for Research.

Pizzie, R., & Kraemer, D. (2017). Avoiding math on a rapid timescale: Emotional responsivity and anxious attention in math anxiety. *Brain and Cognition, 118,* 100-107.

Renaissance Learning. (2011). The research foundation for MathFacts in a Flash: The critical role of automaticity in accelerating math achievement. Wisconsin Rapids, WI: Author. Available online from (L2297) http://doc.renlearn.com/KMNet/R004344828GJF314.p

Richardson, F., & Suinn, R. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counseling Psychology, 19(6)*, 551-554.

Rittle-Johnson, B., Schneider, M., & Star, J. R. (2015). Not a one-way street: Bidirectional relations between procedural and conceptual knowledge of mathematics. Educational Psychology Review, 27(4), 587-597.

Rivera, D. M., & Bryant, B. R. (1992). Mathematics instruction for students with special needs. *Intervention in School and Clinic, 28(2),* 71-86.

Rivera, S. M., Reiss, A. L., & Menon, V. (2005). Developmental changes in mental arithmetic evidence for increased functional specialization in the left inferior parietal cortex. *Cerebral Cortex,* 15(11), 1779-1790.

Roman, H. (2004). Why Math is So Important*. Tech Directions, 63(10),* 16-18.

Shi, Z., Gao, X., & Zhou, R. (2014). Emotional working memory capacity in test anxiety. *Learning and Individual Differences*, *32(C),* 178-183.

Shi, Z., & Lie, P. (2016). Worrying thoughts limit working memory capacity in math anxiety. *PLoS ONE, 11(10),* p. e0165644. https://doi.org.10.1371/journal.pone.0165644

Skinner C.H. (1998) Preventing Academic Skills Deficits. In: Watson T.S., Gresham F.M. (eds) Handbook of Child Behavior Therapy. *Issues in Clinical Child Psychology.* Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-5323-6_4

Skinner, C. H., & Schock, H. H. (1995). Best practices in mathematics assessment. *Best practices in school psychology*, 731-740.

Sorvo, Riikka, Koponen, Tuire, Viholainen, Helena, Aro, Tuija, Räikkönen, Eija, Peura, Pilvi, . . . Aro, Mikko. (2017). Math anxiety and its relationship with basic arithmetic skills among primary school children. *British Journal of Educational Psychology, 87(3),* 309-327.

Stoehr, K. (2017). Mathematics anxiety: One size does not fit all. *Journal of Teacher Education, 68(1),* 69-84.

Suinn, R. M. (1971). The Application of Short-Term Video-Tape Therapy for the Treatment of Test Anxiety of College Students. Final Report.

Supekar, K., Iuculano, T., Chen, L., & Menon, V. (2015). Remediation of Childhood Math Anxiety and Associated Neural Circuits through Cognitive Tutoring. The Journal of Neuroscience : The Official Journal of the Society for Neuroscience, 35(36), 12574-12583.

Swanson, H., Beebe-Frankenberger, M., & Harris, Karen R. (2004). The relationship between working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology, 96*(3), 471-491.

Swanson, H., & O'Connor, R. (2009). The role of working memory and fluency practice on the reading comprehension of students who are dysfluent readers. *Journal of Learning Disabilities, 42*(6), 548-575.

Swars, S., Daane, C., & Giesen, J. (2006). Mathematics Anxiety and Mathematics Teacher Efficacy: What Is the Relationship in Elementary Preservice Teachers*? School Science and Mathematics, 106(7),* 306.

Tiedemann, J. (2000). Parents' gender stereotypes and teachers' beliefs as predictors of children's concept of their mathematical ability in elementary school. *Journal of Educational Psychology*, *92*(1), 144. https://doi.org/10.1037/0022-0663.92.1.144

Tobias, S. (1986). Anxiety and cognitive processing of instruction. *Self-related cognition in anxiety and motivation*, 35-54.

Tolar, T. D., Lederberg, A. R., & Fletcher, J. M. (2009). A structural model of algebra achievement: a computational fluency and spatial visualization as mediators of the effect of working memory on algebra achievement. *Educational Psychology,* 29(2), 239-266. https://doi.org/10.1080/01443410802708903

Vinson, B. M. (2001). A comparison of preservice teachers' math-ematics anxiety before and after a methods class emphasizing manipulatives. Early Childhood Education Journal, 29(2), 89–94. https://doi.org/10.1023/A:1012568711257

Warner, R. M. (2013). *Applied statistics: From bivariate through multivariate techniques* (2nd ed). Los Angeles, CA: SAGE.

Wigfield, A., & Meece, J. L. (1988). Math anxiety in elementary and secondary school students. *Journal of Educational Psychology*, *80*(2), 210.

Wilkinson, R., & Bevir, M. (Ed.) (2007). The World Economic Forum. In *The Encyclopedia of Governance* Sage Publications Ltd.

Wine, J. D. (1971). Test **anxiety** and direction of attention. *Psychological Bulletin*, *76*, 92–104.

Wine, J. D. (1980). Cognitive-attentional theory of test **anxiety**. In I. G.Sarason (Ed.), *Test **anxiety**: Theory, research and applications* (pp. 349–385). Hillsdale, NJ: Erlbaum.

Wood, G., Pinheiro-Chagas, P., Júlio-Costa, A., Micheli, L., Krinzinger, H., Kaufmann, L., . . . Haase, V. (2012). Math anxiety questionnaire: Similar latent structure in Brazilian and German school children. *Child Development Research, 2012*, 10.

Wooden, J. (1988). *They call me coach.* Chicago: Contemporary Books.

Woodward, J. (2006). Developing automaticity in multiplication facts: Integrating strategy instruction with timed practice drills. Learning Disability Quarterly, 29(4), 269-289.

Wu, H. (1999). Basic skills versus conceptual understanding: A bogus dichotomy in mathematics education. *American Education, 23,* 14-19, 50-52.

Yee, D., & Eccles, J. (1988). Parent perceptions and attributions for children's math achievement. *Sex Roles 19(5-6),* 317–333. https://doi.org/10.1007/BF00289840

Zaman, M. (2010). The effects of task fluency and concurrent reinforcement schedules on student choice allocation between math tasks. ProQuest Dissertations and Theses.

APPENDICES

LIST OF APPENDICES

Appendix Page

Appendix A 85
Appendix B 86
Appendix C 88
Appendix D 90
Appendix E 91
Appendix F 94

APPENDIX A

CBM Scoring Procedures

Scoring Procedures:

Although many scoring approaches focus solely on fluency scores, to best match student responding to the optimal intervention accuracy rates are needed as well. To meet these needs it is recommended that student performance is reported using digits correct per minute (DC/M) and percentage of digits correct (ACC). To score each probe, count the number of *digits correct* (DC), count the number of possible digits (i.e., include incorrect digits and/or skipped problems), and record the duration of the assessment period (e.g., 2 minutes). To determine DC/M divide the number of DC by the duration of assessment. To determine ACC divide DC by the number of possible digits and multiply by 100 ((DC/PD) x100=_%).
Basic Scoring Procedures:

1. Score digit correct when the correct number is written in proper column.

2. Score digit incorrect if correct number is not written in proper column or number is illegible.

3. Score digit(s) of problem incorrect if the student marks an ‘X’ through, or skips, a problem.

4. Score digit as correct if student clearly writes the correct number in reverse

If a student skips over problems it is likely that the child cannot accurately complete the problem or the problem takes a large amount of response effort to complete – regardless the problem is not known to mastery. A DC/M score of a student who skips to complete easy problems and/or avoid difficult problems will not produce a valid representation of the student’s computation skill and will result in an elevated DC/M score with high ACC due to the students self-selection of problems. This lack of validity will compromise educational decision making associated with CBM (e.g., screening, progress monitoring).

Scoring Examples.

4	8	7	5	7	3	36	7
+ 5	+ 9	- 4	x 5	x 8	x 8	÷ 6	9 ⟌72
9	16	3	25	63	21	6	

1/1 DC 1/2 DC 1 /1 DC 2/2 DC 0/2 DC 1/2 DC 1/1 DC
0/1 DC Total: (7/12= 58% ACC)

Deno, S. L., & Mirkin, P. (1977). *Data-based program modification: A manual.* Reston, VA: Council for Exceptional Children.

APPENDIX B

Mathematics Anxiety Scale for Children

Instructions:

Please give each sentence a score in terms of how nervous you feel during each situation. Use the scale at the right side and circle the number which you think best describes how you feel.

	☺			☹
	Not nervous	A little bit nervous	Very nervous	Very very nervous
1. Getting a new math textbook	1	2	3	4
2. Reading and interpreting graphs or charts	1	2	3	4
3. Listening to another student explain a math problem	1	2	3	4
4. Watching a teacher work a mathematics problem on the chalkboard	1	2	3	4
4. Walking into a math class	1	2	3	4
6. Looking through the pages in a math book	1	2	3	4
7. Starting a new chapter in a math book	1	2	3	4
8. Thinking about math outside of class	1	2	3	4
9. Picking up a math book to begin working on a homework assignment	1	2	3	4

10. Working on mathematical problems, such as “If I spend $3.87 at the store, how much change will I get from a $5 bill?”	1	2	3	4
11. Reading a formula in science	1	2	3	4
12. Listening to the teacher in a math class.	1	2	3	4
13. Using the tables in the back of a math book	1	2	3	4
14. Being told how to interpret mathematics statements.	1	2	3	4
15. Being given a homework assignment of many difficult math problems which is due the next time	1	2	3	4
16. Thinking about a math test one day before the test	1	2	3	4
17. Doing a long division problem	1	2	3	4
18. Taking a quiz in math class	1	2	3	4
19. Getting ready to study for a math test	1	2	3	4
20. Being given a math quiz that you were not told about	1	2	3	4
21. Waiting to get a math test returned in which you expect to do well	1	2	3	4
22. Taking an important test in a math class	1	2	3	4

APPENDIX C

School of Teaching, Learning and Educational Sciences

PARENT CONSENT FORM

Research Title

Christina Pynn, M.S.

Oklahoma State University School Psychology

Dear Parent/Guardian,

Your permission is requested for your student to participate in a research study on math anxiety in middle school aged students. Your child's classroom has been selected to participate because this study focuses on fifth and sixth grade students. Please ready the following information carefully before you decide whether to give your permission.

Purpose:

The purpose of this study is to learn more about how to help students be successful and have positive attitudes toward math. We would like to find out if math fact accuracy and fluency is related to the way students feel about math.

Procedures:

First, your child will be asked demographic questions (Name, gender, age, and race). Then they will be asked to answer questions regarding how they feel about math. Lastly, they will be asked to complete 4 1-minunte math worksheets. Once this is complete, your child's will continue their typically school day.

Risks/Confidentiality:

There are no risks with being a part of this project that are not already happening during the school day. All records are kept confidential and will be available only the researcher. Records will be stored in a secure, locked file cabinet and only the research will have access to the information. The information will be included in a doctoral dissertation but will not include any information that will make it possible to identify any participants.

Benefits:

There will be no direct benefits of being in this study. We hope to learn something that will help educators understand how to work with students who experience anxiety when working on math-related tasks. This may give us information on how to prevent negative feelings and poor performance in math.

Participant Rights:

Your child's participation is voluntary. Your decision whether to allow your child to participate will not affect your current or future relations with your school. At the time of the study, your child will be asked if they want to voluntarily participate as well. If at any point you or your child wishes to revoke consent, we well do so.

Contact of Questions:

If you have questions about the research study itself, pleases contact Christina Pynn at cpynn@okstate.edu or at (918) 344-2622. If you have questions about your or your child's rights as a research volunteer, please contact the OSU IRB at (405) 744-3377 or irb@okstate.edu

If you do **NOT** want your child to take part in this research study, (1) check the line below, (2) sign the form, and (3) return in to school with your child.

Note: You do not need to return this form if you would like for your child to participate.

Child's name (please print) ________________________________ Grade _________

I have read this form and do not grant permission for my child to participate in this research study.

____ **No** – My child may **not** take part is this study

Parent/Guardian Signature: __________________________________ Date: ________________

APPENDIX D

CHILD ASSENT FORM

School of Teaching, Learning and Educational Sciences

Research title

Christina Pynn, M.S.

Oklahoma State University School Psychology

Why am I being asked to be in this research study?

We would like to learn more about how to help students be successful in math. We would like to find out if math fact accuracy and fluency is related to the way students feel about math. We would like to ask you to be in this research study.

What will happen during this study?

First, you will be asked a couple questions about yourself (Name, gender, age, and race). Then you will answer questions regarding how you feel about math. Lastly, you will be asked to complete four math activities that will take around 6 minutes to complete. Once that is complete, you will continue doing normal things in your classroom.

Risks: There are no risks with being a part of this project that are not already happening during the school day.

Benefits: There will be no direct benefits of being in this study. We hope to learn something that will other people in the future.

What if I don't want to be in the study?

You do not have to work on this project if you do not want to. You can stop at any time you want. You do not have to do anything that makes you feel uncomfortable or sad.

Would you like to participate in this project?

_____I would like to participate in the project.

____ No, I do not want to participate in the project.

Your Name:__________________________ Date: _______________________

ADDENDIX E

Administration Procedures

Materials:

- ◻ Pencil ◻ Timer ◻ Clipboard (optional) ◻ Administration Directions
- ◻ Student Folders ◻ Alternative Activity Folders

Administration Directions:

- Tell students to get out pencil and pass out student folders
- Ensure each student has a pencil and that correct students get alternative folders
- Have students get out the first pack of papers (assent, math anxiety questionnaire, accuracy probe). Read the following instructions:

  "If you have a [insert color] folder, please get out the first packet of papers. At the top you will see Child Assent Form. If you do not have a [insert color] folder, you may work on the activity in your folder for the remainder of the class period and/or read independently."

- Read assent form. This can be shortened just touch on each section.
- Once students have completed the assent form, read the following instructions

  "Next you will flip your page over and answer a couple questions about yourself. Please circle the answer that best applies to you for the following questions"

- Once students have completed the demographics form, read the following instructions:

  "Thank you for your willingness to participate. Today we will be taking this survey to help better understand your feelings toward math. The survey will consist of 22 situations that you might experience with math. You will need to rate how these situations make you feel. There are four choices: (1) not nervous; (2) a little nervous; (3) very nervous; (4) or extremely nervous. It is important that you answer as honestly as possible, your responses will not be seen by your parents or by your teachers. Please begin by answering the question at the top of the page. If you have any questions while completing this form, please raise your hand and one of us will come over and answer your question. When you finish, please turn your page over face down and wait for further directions. Are there any questions before we begin? OK begin."

- Once students have completed the MASC, read the following instructions

"We're going to work on a math worksheet. Read the problems carefully and work each problem in the order presented, start at the first problem on the page and working across the page from left to right. Be sure to look at the operation sign when solving problems. Do not skip around.

If you do not understand a problem, make your best guess and move on. Once you've tried all of the problems, you may go back to the beginning of the worksheet and try any problems you did not know. You may show your work if that is helpful for you, however you may not use calculators or any other aid. Keep working until you have completed all of the problems or until I tell you to stop. If you finish early, you may flip your page over and wait for further directions. Do you have any questions? OK, begin"

- Start 10-minute timer
- Monitor student procedural adherence. Prompt students if directions are violated. For example:
  - ***"Try to work each problem"***
  - ***"Do not skip problems. If you do not know the answer make your best guess"***
  - ***"Keep working until I tell you to stop"***
  - ***"If you don't know the answer, make your best guess and move on to the next problem"***
- Once 10-minute timer stops say… **"Stop and put your pencils down"**
- Have students get out the next packet in their folder (4-single skill probes stapled together)

"Get out the next page which has math problems on it. When I say "BEGIN," you will have one-minute to answer as many problems as you can. Start at the first problem, work across the page then go to the next row. For these math worksheets, you should work as fast as you can without skipping problems. If you come to a problem that you do not know, mark an 'X' through it and go onto the next problem. Continue working until I tell you to stop. Are there any questions? Ready. Begin"

- When you instruct students to begin start 1-minute timer
- Monitor student procedural adherence. Prompt students if directions are violated. For example:
  - ***"Please work across the page"***
  - ***"Do not skip problems. If you cannot answer mark an 'X' through it"***
  - ***"Keep working until I tell you to stop"***

- After 1-minute elapses, tell the students ***"Stop, please put down your pencil and flip to the next page"***
- Repeat steps for math probes. Directions may be shortened when students demonstrate understanding on procedures.

Steps Completed: / 15

Percentage of steps completed: _________

Initials:__________

ADDENDIX F

IRB Approval

Oklahoma State University Institutional Review Board

Date:	03/05/2021
Application Number:	IRB-20-412
Proposal Title:	Understanding the Relationship Between Mathematics Anxiety and Math Fact Fluency
Principal Investigator:	Christina Pynn
Co-Investigator(s):	
Faculty Adviser:	Gary Duhon
Project Coordinator:	
Research Assistant(s):	
Processed as:	Expedited
Expedited Category:	

Status Recommended by Reviewer(s): Approved

Approval Date: 03/05/2021

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

This study meets criteria in the Revised Common Rule, as well as, one or more of the circumstances for which continuing review is not required. As Principal Investigator of this research, you will be required to submit a status report to the IRB triennially.

The final versions of any recruitment, consent, and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be approved by the IRB. Protocol modifications requiring approval may include changes to the title, PI, adviser, other research personnel, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a status report to the IRB when requested
3. Promptly report to the IRB any harm experienced by a participant that is both unanticipated and related per IRB policy.
4. Maintain accurate and complete study records for evaluation by the OSU IRB and, if applicable, inspection by regulatory agencies and/or the study sponsor.
5. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

If you have questions about the IRB procedures or need any assistance from the Board, please contact the IRB Office at 405-744-3377 or irb@okstate.edu.

Sincerely,
Oklahoma State University IRB

VITA

Christina Louise Pynn

Candidate for the Degree of

Doctor of Philosophy

Dissertation: UNDERSTANDING THE RELATIONSHIP BETWEEN MATHEMATICS ANXIETY AND MATH FACT FLUENCY IN FOURTH AND FIFTH GRADE STUDENTS

Major Field: School Psychology

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in School Psychology at Oklahoma State University, Stillwater, Oklahoma in July, 2022.
Completed the requirements for the Master of Science in Psychometrics at Oklahoma State University, Stillwater, Oklahoma in December, 2018.
Completed the requirements for the Bachelor of Science/Arts in your major at University/College, City, State/Country in Year.

Experience:

300 Hour School-Based Practicum at Skyline Elementary
600 Hour School-Based Practicum at Perry School District
400 Hour Clinic-Based Practicum at OSU School Psychology Clinic
675 Hour ABA Practicum at Cornerstone Behavioral Health
Completing the requirements for a pre-doctoral internship as a clinical intern at the Munroe-Meyer Institute Behavioral Pediatrics and Integrated Care Omaha, NE 2021-2022

Professional Memberships:

School Psychology Graduate Organization (Fall 2017 – Spring 2021)
Vice President (Fall 2019 – Spring 2020)
National Association of School Psychologists (Fall 2017 – Present
Oklahoma School Psychology Association (Fall 2017 – Spring 2021)
American Psychological Association – Division 16 (Fall 2017 – Fall 2021)