A Meta-analysis of the Relation Between Math Anxiety and Math Achievement

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The data and associated files for this meta-analysis are available at https://osf.io/szrhx

The research reported in this paper was supported in part by the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development, National Institutes of Health (Award #HD052120) and Institute of Education Sciences, U.S. Department of Education, through Grant R305A170463 to Florida State University. Views expressed herein are those of the authors and have neither been reviewed nor approved by the granting agencies.

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Abstract

Meta-analyses from the 1990s have previously established a significant, small-to-moderate, and negative correlation between math achievement and math anxiety. Since these publications, research has continued to investigate this relation with more diverse samples and measures. Thus, the goal of the present meta-analysis was to provide an update of the math anxiety-math achievement relation and its moderators. Analyzing 747 effect sizes accumulated from research conducted between 1992 and 2018, we found a small-to-moderate, negative, and statistically significant correlation (r = -.28) between math anxiety and math achievement. The relation was significant for all moderator subgroups, with the exception of the relation between math anxiety and assessments measuring the approximate number system. Grade level, math ability level, adolescent/adult math anxiety scales, math topic of anxiety scale, and math assessments were significant moderators of this relation. There is also a tendency for published studies to report significantly stronger correlations than unpublished studies but, overall, large, negative effect sizes are under-reported. Our results are consistent with previous findings of a significant relation between math anxiety and math achievement. This association starts in childhood, remains significant through adulthood, is smaller for students in grades 3 through 5 and postsecondary school, is larger for math anxiety than for statistics anxiety and for certain math anxiety scales, and is smaller for math exam grades and samples selected for low math ability. This work supports future research efforts to determine effective math achievement and math anxiety interventions, which may be most helpful to implement during childhood.

Keywords: meta-analysis, math anxiety, math achievement, grade level

Public Significance Statement: The present meta-analysis finds a robust association between math anxiety and math achievement, indicating that people who report higher feelings of anxiety towards math tend to have lower math achievement. The relation is weaker for people at certain grade levels (grades 3 through 5 and college students), depends on the scales used to measure math anxiety, is stronger for math anxiety compared to statistics anxiety, and is weaker for math exam grades and for low math ability samples. Math anxiety is experienced by many individuals throughout development. Its association with math achievement makes math anxiety an important factor to consider for improving math experiences, academic outcomes, and STEM career participation.

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Research aimed at understanding how to improve achievement in mathematics has long been stimulated by the importance of its use in everyday life (OECD, 1999). More recently, a clear national and international priority has been made to increase engagement in fields that require strong mathematics skills, such as fields in science, technology, engineering, and mathematics (STEM; Corbett & Hill, 2015; Olson & Riordan, 2012). Despite this importance, recent work has shown declines in math achievement in students across the globe (Gottfried, Marcoulides, Gottfried, Oliver, & Guerin, 2007; Kastberg, Chan, & Murray, 2016; Wijsman, Warrens, Saab, Van Driel, & Westenberg, 2016). For example, the 2015 Program for International Student Assessments (PISA) report found a significant decline from 2012 to 2015 in the average 15-year-old students' math achievement scores from at least a third of countries sampled, including the United States, China (i.e., Hong Kong), and Brazil (OECD, 2016). In light of this decline, it is imperative to continue to work to understand the nature of math achievement and associated factors.

Negative affect related to math has been a critical focus of the research aimed at understanding how to increase math knowledge (Aiken, 1970; Foley et al., 2017; McLeod, 1994). One affective factor that has been found to play a central role in math achievement is *math anxiety*, defined as the fear and worry related to math stimuli and situations (Ashcraft, 2002; Richardson & Suinn, 1972). Meta-analyses investigating the relation between math anxiety and math achievement from the 1990s highlight the primacy of this relation; both Hembree's (1990) and Ma's (1999) statistical analyses of the strength of the association found significant small-to-moderate negative associations between math anxiety and math achievement (Hembree: rs ranged from -.25 to -.40; Ma: $r = -.27$). Overall, aggregated evidence from these two meta-analyses suggest that many students with higher levels of math anxiety tend to also have lower levels of math achievement.

Over the past twenty years since the last of these statistical reviews, research studying the relation between math anxiety and math achievement has continued to flourish. A closer look at these previous meta-analyses, along with publications that have surfaced since their release, reveals that there are specific questions that need to be clarified surrounding the nature of the relation between math anxiety and math achievement. For example, although recent work has been conducted with different age groups, it is unclear whether the relation is consistently evident in student populations younger than grade 4 (Ganley & McGraw, 2016; Harari, Vukovic, & Bailey, 2013) or in non-student adult populations (Hart & Ganley, 2019). The scope of recent research has become more nuanced with regard to the demographics of samples studied and measures used to assess math anxiety and math achievement. As such, a synthesis of this work can provide a clearer picture of the magnitude of the relation, particularly for complexities of the relation that remain unclear.

There were two aims for the present study. The primary aim was to conduct a meta-analysis that takes into account the surge of research that has occurred since Ma's (1999) meta-analysis on the overall association between math anxiety and math achievement. The secondary aim was to investigate whether this relation is moderated by certain factors. Specifically, we examined whether sample demographic characteristics of gender, race/ethnicity, country, or grade level moderated the relation between math anxiety and math achievement. We also examined whether teachers or samples selected for low math ability had differential relations compared to non-teacher samples and samples not selected for low math ability, respectively. Finally, we examined whether measure characteristics, such as the types of measures used to assess math anxiety and math achievement or the content area assessed by the math assessment, moderated the relation.

Importance of Math Anxiety and Math Achievement

Math anxiety and math achievement have both been theorized to be important correlates of educational and career outcomes (Wigfield & Eccles, 2000). High levels of math anxiety as well as low math achievement and beliefs about math ability early in development have been found to significantly relate to avoidance of later educational opportunities in math (Espino, Pereda, Recon, Perculeza, & Umali, 2017; Hembree, 1990; Hurst & Cordes, 2017; Meece, Wigfield, & Eccles, 1990). Math anxiety has also been found to relate to the adoption of achievement goal types that are linked with reduced content mastery, such as performance-avoidance and mastery-avoidance goal orientations (Gonzalez-DeHass, Furner, Vásquez-Colina, & Morris, 2017). Furthermore, math anxiety and math achievement have been associated, separately, with high school and college career interests and choices in STEM fields (Ahmed, 2018; Lauermann, Chow, & Eccles, 2015; Watt, et al., 2017). For example, one study found that students who had consistently low or decreasing math anxiety from middle school through high school were more likely to choose STEM majors during postsecondary education than were students with consistently high or increasing math anxiety from middle to high school (Ahmed, 2018).

Throughout development, math anxiety and math achievement guide people down pathways that lead to different learning outcomes, educational pursuits, and career choices. Despite the importance of math anxiety and math achievement in shaping these pathways, inequities in these factors have been reported for certain groups, including females, people of racial and ethnic minority backgrounds, and students with learning disabilities (Catsambis, 1994;

Devine et al., 2012; Dowker, Sarkar, & Looi, 2016; Else-Quest, Hyde, & Linn, 2010; Fan, Chen, & Matsumoto, 1997; Hall, Davis, Bolen, & Chia, 1999; Sonnenschein & Galindo, 2015; Suárez-Pellicioni, Núñez-Peña, & Colomé, 2016). For example, some evidence suggests a greater tendency for females to self-report high levels of math anxiety compared to males (Devine, Fawcett, Szűcs, & Dowker, 2012; Hart & Ganley, 2018; Wigfield & Meece, 1988). Regarding math achievement, other work has found gender differences that vary in direction of math performance levels. Some findings have suggested that boys have lower math achievement and other findings have suggested the same for girls, with many of the differences in findings between studies primarily depending on the measure of math achievement used, age of sample, and ability level of students (Cimpian, Lubienski, Timmer, Makowski, & Miller, 2016; Voyer & Voyer, 2014). As another example of group inequities, some studies have found that samples of African American students achieve lower math scores compared to samples of mostly European American students (Else-Quest, Mineo, & Higgins, 2013; Hall et al., 1999; Sonnenschein & Galindo, 2015), although socioeconomic status may explain these racial and ethnic differences (Lubienski, 2002). Given that math anxiety and math achievement are instrumental in understanding a person's academic and career choices, it is important to understand whether group inequities found in math anxiety and math achievement, separately, are also prevalent in their relation. In the case where there is a stronger relation between math anxiety and math achievement for certain groups that also tend to have lower achievement or higher anxiety, these groups would be most in need of targeted interventions to reduce math anxiety or improve math skills in order to minimize negative academic-related outcomes.

Math Anxiety-Math Achievement Link

Numerous theories have been posited to explain the negative relation between math anxiety and math achievement, with much of the initial work rooted in theories derived from the general anxiety and test anxiety literatures (Eysenck & Calvo, 1992; Liebert & Morris, 1967; Wine, 1971) and adapted to accommodate the math-specific context. The primary theories explaining the anxiety-performance relation are described briefly below (for detailed reviews, see Beilock & Maloney, 2015, Carey, Hill, Devine, & Szucs, 2016, or Foley et al., 2017).

One major theory explaining the anxiety-performance link is the *processing efficiency theory*. In this theory, cognitive worry interferes with cognitive capacities required for efficient and accurate performance (Eysenck & Calvo, 1992). This reduction in efficiency is theorized to be attributable primarily to an overload of working memory resources (Ashcraft, Kirk, & Hopko, 1998; Caviola, Mammarella, Cornoldi, & Lucangeli, 2012). Thus, in the presence of a math-related stressor such as solving a multiplication problem or learning about the commutative property of multiplication, math anxiety is proposed to use working memory resources, which would otherwise be available to solve the problem or learn math content. An expanded version of this theory, the *attentional control theory*, further proposes that initial attention to a task is controlled by either the stimulus-driven system or the goal-directed system (Eysenck, Derakshan, Santos, & Calco, 2007). In the case of math anxiety, a math stressor activates the stimulus-driven system, which then undermines the goal-directed system of completing the math task (Eysenck et al., 2007). Furthermore, negative cognitive biases, such as tendencies to attend to specific stimuli and interpret them as threatening, are thought to be part of the initial processing components that enable the distraction, making it difficult for an individual to focus on the details of a math problem and instead fixate on the negative thoughts (Macleod & Mathews, 2012). Taken together, these theories suggest that, in the presence of math stimuli, the attention of a person with math anxiety, who may have a tendency to attend to and interpret math stimuli as threatening, gets redirected from the goal of completing the task to the math stressor. Ultimately, this redirection of attention reduces the available working memory to efficiently and accurately complete the math task at hand.

Another theory has suggested a causal relation in the opposite direction of the attentional control theory, whereby poor math achievement causes heightened math anxiety. The *deficit model* suggests that poor basic number processing (e.g., counting, subitizing) is the primary reason for anxiety during math situations (Maloney, Risko, Ansari, & Fugelsang, 2010; Núñez-Peña & Suárez-Pellicioni, 2014; Tobias, 1986). This theory suggests that deficits in basic numerical processing lead to negative encounters with math, which then creates anxiety during subsequent math-related experiences and tasks. Several studies have provided empirical support for this model, finding that students with high math anxiety perform worse than their lower math anxiety counterparts in number magnitude representation skills (Maloney et al., 2010; Núñez-Peña & Suárez-Pellicioni, 2014). Some researchers have further extended the math deficit model to individuals with math learning disabilities, providing empirical evidence suggesting that these populations are more susceptible to math anxiety than individuals without math learning disability (Lai, Zhu, Chen, & Li, 2015; Wu, Wilcutt, Escovar, & Menon, 2014). However, other work has failed to find support for this interpretation (Devine, Hill, Carey, & Szűcs, 2017).

Though the attentional control theory and the deficit model could be seen as competing conceptualizations of the math anxiety-math achievement link, the opposing causal directions found between studies testing these theories may instead be artifacts of study design. Specifically, longitudinal studies often find that early math achievement influences later math anxiety (Ma & Xu, 2004; Meece, Wigfield, & Eccles, 1990), while experimental studies find that math anxiety causes math achievement difficulties due to math anxiety's online use of working memory capacities (Ashcraft, Krause, & Hopko, 2007). Importantly, some work has attempted to reconcile both theories by suggesting that these two causal pathways occur simultaneously (Ashcraft et al., 2007; Carey et al., 2016; Pekrun, 2006). More generally, Pekrun's control-value theory of achievement emotions suggests that achievement emotions and achievement are reciprocally related in a feedback loop (Pekrun, 2006). With regard to the domain of math and the emotion of anxiety, the *reciprocal theory* combines the two theoretical perspectives of the attentional control theory and the deficit model that assume different causal relations, and proposes that math anxiety and math achievement are causally related to each other bidirectionally (Devine et al., 2012; Gunderson, Park, Maloney, Beilock, & Levine, 2018; Ma & Xu, 2004). Research has found supporting evidence for this perspective, finding differing magnitudes of causal importance between math anxiety and math achievement depending on the age of the sample (Cargnelutti, Tomasetto, & Passolunghi, 2017; Gunderson et al., 2018; Pekrun et al., 2017).

Potential Moderators of the Math Anxiety-Math Achievement Link

Based on previous empirical evidence, the relation between math anxiety and math achievement has been theorized to vary depending on a number of sample and study factors. For example, the two meta-analyses from the 1990s that investigated this relation found several factors differentiated the strength of the negative correlation, including the gender of primary and secondary school students (Hembree, 1990) and the assessments used to measure math achievement (Ma, 1999). Of importance, many changes in social-contextual factors and study measures have occurred over the last 25 years that may contribute to varying strengths in the relation that were not evident or have changed since the publication of previous meta-analyses. Accordingly, it is important to conduct an updated and thorough moderator analysis on the current available work in order to understand the nuanced between-study differences that may impact the strength of the reported math achievement-math anxiety relation. It is also important to note that, for the moderators, the difference in the relations between subgroups (i.e., males, females) is generally theorized to vary in *magnitude* (i.e., small versus moderate correlation) and not in direction (i.e., positive versus negative correlation), which is generally found to be negative.

Demographics of sample.

Gender. Previous research has found gender differences in self-reported math anxiety, with higher self-reported scores found for girls than for boys and for women than for men (Devine, et al., 2012; Hart & Ganley, 2019). Small gender differences have also been found in math achievement, although the direction is less clear-cut (Cimpian et al., 2016; Hyde, Fennema, & Lamon, 1990). The evidence so far on gender differences in the relation between math anxiety and math achievement has also been mixed. The two meta-analyses from the 1990s that investigated this relation each came to a different conclusion on this topic: Hembree (1990) found a stronger negative correlation for male students compared to female students in grades 5 through 12 but not for students in postsecondary school, whereas Ma (1999) found the correlations to be similar for females and males. Some theory (Aiken, 1970) as well as recent empirical evidence (Hill et al., 2016) adds yet another possible conclusion, suggesting that a stronger negative relation between math anxiety and math achievement exists for females compared to males. In the present meta-analysis, we will attempt to clarify these contradictory findings by empirically testing whether gender moderates the relation between math anxiety and math achievement, using the combined power of effect sizes from studies reporting correlations for completely male or female samples.

Race, ethnicity, and country. In addition to gender differences in the relation between math anxiety and math achievement, there may be significant differences that are evident between racial groups, ethnic groups, or country of origin. Variability in math achievement and math anxiety, separately, has been found between samples from different countries and samples of different racial and ethnic backgrounds (Cipora, Szczygiel, Willmes, & Nuerk, 2015; Else-Quest, Mineo, & Higgins, 2013; OECD, 2016; Pretorius & Norman, 1992; Young & Young, 2016; Zabulionis, 2001). Importantly, there may be variations that stem from the education systems between countries and within countries that may be associated with the differences seen in math anxiety and math achievement between racial/ethnic groups and countries. Investigating whether the differences further appear in the relation between math anxiety and math achievement will serve to better inform the roles of educational practices and policies between countries and for different racial/ethnic groups.

When examining the influence of race on the correlation between math anxiety and math achievement, previous work has found that the magnitude of the correlation did not differ for samples that consisted of a homogenous race (e.g., effect sizes from majority European sample or majority Asian sample combined into one group) compared to samples that were racially diverse (Ma, 1999). However, it is unclear whether there is enough information available from different racial groups within a specific country in the current literature that will allow for meaningful comparisons between these more specific groups (e.g., majority African American sample, majority Asian American sample, majority European American sample). We will examine whether these potential differences can be tested in the present study.

Additionally, some work has been done to clarify whether there are differences in the relation between math anxiety and math achievement between countries (Engelhard, 1990; Foley et al., 2017; Verkijika & De Wet, 2015). However, confounds related to the age of the study samples may limit the generalizability of study findings. For example, analyses conducted from international, large-cohort data sets of 15-year-old students, such as the PISA, have reported significant differences across countries in the magnitude of the negative relation between math anxiety and math achievement (Foley et al., 2017; Lee, 2009). Several other studies investigating this relation in younger student samples across different countries have found varying correlations, ranging from not significant to significant (Hill et al., 2016; Ganley & McGraw, 2016; Krinzinger et al., 2009; Vukovic, Kieffer, Bailey, & Harari, 2013). Both of these examples suggest that differences in the size and significance of the relation for between different countries may be due to the age of the sample as well as the country of the sample. To date, no work has examined between-country differences in the relation between math anxiety and math achievement with a study sample encompassing participants of various age levels. Thus in the present meta-analysis, we aim to fill these gaps and examine whether the relation between math anxiety and math achievement appears different across varying racial and ethnic groups and across countries with samples of all ages.

Age and grade level. Research has investigated the relation between math anxiety and math achievement in students of different ages. Notably though, the two meta-analyses from the 1990s did not report effect sizes from samples of students younger than grade 4 (Hembree, 1990; Ma, 1999). The absence of younger samples in these two meta-analyses likely occurred because no research investigating this relation had been conducted on younger students; at this point in time, there were not many, if any, valid measures available to assess math anxiety in students younger than grade 4 (Suinn, Taylor, & Edwards, 1988).

In the years since these publications, multiple researchers have developed and validated math anxiety measures for use with students as young as grade 1, with some of this work finding evidence for high levels of math anxiety in some students at these young ages (Ganley & McGraw, 2016; Harari et al., 2013; Ramirez, Gunderson, Levine, & Beilock, 2013; Wu, Amin, Barth, Malcarne, & Menon, 2012). Importantly though, studies investigating the relation between math anxiety and math achievement in young children have found inconsistent results (Harari et al., 2013; Hill et al., 2016; Jameson, 2014; Krinzinger, Kaufmann, & Willmes, 2007; Thomas & Dowker, 2000). Some evidence suggests that the association between math anxiety and math achievement for 6 to 9-year-olds is not significant (Thomas & Dowker, 2000), whereas other research has found significant associations in samples of young children (Harari et al., 2013; Krinzinger et al., 2007). Some of this work suggests that, when found to be significant, this relation in younger children is due to general anxiety that is not math-specific (Hill et al., 2016). The relation found in samples of young children may also be confounded by geographic differences or anxiety measure differences, a possibility that is discussed in other sections of this manuscript.

As for adolescents and young adults, a large body of research has found small-to-moderate negative correlations between math anxiety and math achievement in middle school, high school, and undergraduate student samples (Hembree, 1990; Ma, 1999). A large amount of this work has been with undergraduate college students, and this methodological choice is likely due to the ease with which an undergraduate sample can be accessed for research purposes in a university setting. Some recent work has also examined whether the relation may differ in non-student adult samples (Beilock, Gunderson, Ramirez, & Levine, 2010; Hart & Ganley, 2019; Maloney, Ramirez, Gunderson, Levine, & Beilock, 2015), finding similar small-to-moderate correlations in these samples. Overall though, it is currently unclear whether the magnitude of the relation varies in size at different points of development.

Teachers. In addition to demographic characteristics such as gender, race, and age, a person's career choice may moderate the relation between math anxiety and math achievement. Specifically, teachers, often elementary-level educators, have been a group of professionals that have been studied with regard to their math anxiety. Previous research has found higher levels of math anxiety for elementary education majors compared to people in other college majors like the social sciences and business (Hembree, 1990). This higher than typical math anxiety in teacher samples may have short- and long-term impacts on the students they educate. Some research further suggests that teachers' math anxiety may impact their students' math performance (Beilock et al., 2010; Ramirez, Hooper, Kersting, Ferguson, & Yeager, 2018). Thus, a comparison of this relation for teacher samples compared to other samples is imperative as it is unclear whether teacher math anxiety is more or less related to their math knowledge when compared to the rest of the population.

Students with low math ability. Another subsample where we may find a different relation between math anxiety and math achievement is students with low math ability. More broadly, research has found that math anxiety levels were similar for students with low and average levels of math ability (Hembree, 1990). Importantly though, according to the deficit model described earlier in this paper, which theorizes that poor math performance leads to math anxiety, it is suggested that students with low math ability may have higher math anxiety than their counterparts with average math abilities. Some behavioral studies as well as brain imaging studies have found supporting evidence for this hypothesis (Lindskog, Winman, & Poom, 2017; Maloney et al., 2010; Núñez-Peña & Suárez-Pelicioni, 2014). However, whether there is a difference in the magnitude of the relation between math anxiety and math achievement for students with low math ability compared to students who do not have low math ability is still unclear. Therefore, it is important to understand whether a differential trend exists in this relation for students with low math ability compared to samples that are not selected for low math ability.

Measure characteristics.

Math anxiety scales. With the current availability of a variety of scales to assess math anxiety, it may be useful for researchers to know how each scale differentially relates to math achievement when selecting their study measures. One of the first and most well-known scales to measure math anxiety is the 98-item Math Anxiety Rating Scale (MARS; Richardson & Suinn, 1972). In his 1999 meta-analysis, Ma compared the correlations of samples using the MARS (k = 15) to samples using other, non-MARS scales (k = 22). Importantly, he found no differences in the correlations between these two groups of studies, suggesting that the MARS and non-MARS scales produced similar correlations with math achievement.

However, since Ma's (1999) meta-analysis, many newer and shorter math anxiety scales have been developed using the most current psychometric methods (e.g., Ganley & McGraw, 2016; Harari et al., 2013; Hopko, Mahadevan, Bare, & Hunt, 2003; Núñez-Peña, Guilera, & Suárez-Pellicioni, 2014). Some scales have also been adapted from previous scales for a variety of reasons, such as to accommodate young children's language abilities (e.g., Ganley & McGraw, 2016; Harari et al., 2013), to be translated and better understood in other languages and countries (e.g., Carey, Hill, Devine, & Fuchs, 2017), and to assess anxiety in more specific math content areas like statistics (e.g., Baloğlu, 2002). In light of the number of novel math anxiety scales, it is important to examine whether the math anxiety scale used moderates the relation between math anxiety and math achievement.

Components of math anxiety. Some of the work investigating math anxiety has treated it as a unidimensional construct (Richardson & Suinn, 1972); however, some researchers have investigated whether math anxiety is multidimensional (Ganley & McGraw, 2016; Lukowski et al., 2016; Rounds & Hendel, 1980; Plake & Parker, 1982). Evidence from factor analyses has indicated that math anxiety is multidimensional, suggesting that, depending on the items used within a scale, math anxiety can be made up of a variety of components. One distinction that has been made is between worry, or the cognitive dimension of anxiety, and emotionality, or the physiological dimension of anxiety (Liebert & Morris, 1967). Worry consists of negative expectations and self-deprecating thoughts about a math situation, whereas emotionality refers to the dread and unpleasant physical sensations associated with a math situation.

Another distinction has been made between math learning anxiety and math evaluation anxiety (Plake & Parker, 1982; Hopko et al., 2003). Math learning anxiety involves responses to situations surrounding learning in a math classroom, such as seeing the teacher write a math equation on the board and opening up a math textbook. Math evaluation anxiety involves responses to studying for and taking math tests. These two components were found to make up a shortened 24-item version of the 98-item MARS (Richardson & Suinn, 1972), developed by Plake & Parker (1982). Beyond these four components, research has also found other similar components to these that involve anxiety associated with various aspects of math situations and tasks, such as numerical processing anxiety (Wu et al., 2012), math problem-solving anxiety (Gierl & Bisanz, 1995), and math error anxiety (Jameson, 2013). Although there may be overlap between these categories (i.e., an item may ask about feeling worried while learning math, combining components of worry and math learning anxiety), researchers have primarily distinguished math anxiety between worry and emotionality or between math learning anxiety and math evaluation anxiety components of math anxiety.

Some research has been done to examine whether there are differences in the relations with math achievement for different components of math anxiety (Ganley & McGraw, 2016; Lukowski et al., 2016). For example, Wigfield & Meece (1982) found that the component of worry had weaker relations with two assessments of math achievement (both *r*s = .02) than did the component of negative affective reactions and math achievement (*r*s = -.22 and -.26). Thus, it is important to understand whether, in the work currently available, the component of math anxiety is an important distinction to take into account when examining the relation between math anxiety and math achievement.

Math assessments. In addition to the math anxiety scale used, the strength of the relation between math anxiety and math achievement may also depend on the type of assessment used to measure math achievement. In general, the strength of the relation between anxiety and performance is strong for high-stakes achievement measures, such as the SAT (Cassady & Johnson, 2002). High-stakes testing situations may invoke high levels of anxiety and, as suggested by the attentional control theory, this may lead to a stronger association with achievement than other testing situations. However, meta-analytic work has shown a lower-magnitude correlation between math anxiety and math achievement for standardized achievement tests in comparison to researcher-made math tests and teacher reports of children's math achievement (Ma, 1999). It is not yet known whether evidence from recent work supports the potential theory that a stronger relation exists between math anxiety and high-stakes, standardized math tests compared to low-pressure testing situations, like researcher-developed measures. Additionally, it may be important to test whether there are differences in the relation with math anxiety for more diverse math achievement measures, such as exam scores in math classes, and between more specific contexts of standardized achievement measures, such as college entrance exams and tests administered in lab experiments.

Math content. Previous work has found significant, small-to-moderate correlations between math anxiety and different math content areas, such as computation ($r = -.25$), math concepts ($r = -.27$), problem solving ($r = -.27$), and abstract reasoning ($r = -.40$; Hembree, 1990). Despite these significant correlations, most of these effect sizes were constrained to samples in grade 7, high school, and postsecondary school. To extend this work, it is prudent to further examine what the relation between math anxiety and math achievement looks like for more specific math content areas typically developed or learned during childhood, such as approximate number system or basic number knowledge. Additionally, with the number of studies that have examined this relation in the past 25 years, it may be possible to expand the search to include samples of a wider range of ages.

Though previous work did find significant relations between math anxiety and math achievement for some content areas (Hembree, 1990), math content area has yet to be tested as a moderator of the relation between math anxiety and math achievement. There is some empirical evidence indicating that there may be different relations between math anxiety and math tests that assess certain math content; for example, difficult math problems with high cognitive demands are more impacted by math anxiety in comparison to those math problems demanding less cognitive resources (Ashcraft, 2002). Additionally, early math skills have been found to be important for later math skills (Jordan, Kaplan, Raminemi, & Locuniak, 2009; Siegler et al., 2012); as such, testing whether there are differential relations between math anxiety and different content areas that typically develop and are learned during specific points in development could have important implications on our understanding of math learning and practices in education.

The Present Study

Throughout the past several decades, researchers have made a strong collective effort to understand the factors that significantly relate to math achievement, homing in on math anxiety as a crucial correlate. In the current meta-analysis, we investigated two main research questions. First, we examined the strength of the overall correlation between math anxiety and math achievement across studies investigating this relation from 1992 through 2018. Second, we conducted a moderator analysis to investigate whether the size of the correlation between math anxiety and math achievement differed depending on study and sample characteristics, specifically 1) gender, 2) race/ethnicity, 3) country, 4) grade level, 5) teacher samples, 6) low math ability samples, 7) math anxiety scale, 8) component of math anxiety, 9) math assessment type, and 10) content area of math assessment.

Method

Study Search and Selection

The search for relevant articles for the present study consisted of two techniques. The first technique was based on Ma's (1999) meta-analytic search techniques. We conducted an online database search across three journal databases that focus on literature in psychology, education, and medicine: PsycInfo, Educational Resources Information Center (ERIC), and Medline. In order to remain consistent with the search terms and Boolean operators across databases, we used the ProQuest platform for each database search. We queried any available document that contained our search terms, including both peer-reviewed publications and grey literature, such as dissertations, theses, reports, and conference proceedings. The selected year criteria for these database searches ranged from January of 1992, the year of Ma's (1999) last relevant study, to any documents or publications available in May of 2018.

In order to conduct an exhaustive search through our query of online databases, we expanded on the three search terms of *mathematics*, *anxiety*, and *achievement* originally used by Ma (1999). We included the following search terms, making sure to select for articles that included both the word math, or a related synonym, and the word anxiety (denoted by the connecting AND): *mathematics, math, maths, arithmetic, numerical, geometry, statistics, calculus,* OR *algebra* AND *statistics anxiety, mathematics anxiety, math anxiety,* OR *maths anxiety*. We specifically searched for these terms if they appeared anywhere in a document.

For our second search technique to procure relevant studies for our literature search, we sent a message to the Cognitive Development Society (CDS) listserv and requested unpublished data or manuscripts on the relation of math anxiety and math achievement that could be included in the present meta-analysis. Of note, this solicitation of data from the CDS listserv also included several unpublished effect sizes from studies in the labs headed by two of the authors of the current study.

Studies were eligible to be included in the meta-analysis if they met the following inclusionary criteria. First, studies had to either report a zero-order correlation coefficient between math anxiety and math achievement or have collected data that made the calculation of a zero-order correlation coefficient possible. If the relation was not reported directly in the paper but data were collected, or if multivariate regression coefficients were reported, zero-order correlations were requested from authors via email. Second, studies had to measure math achievement or math performance using a math-related assessment. Studies assessing math achievement as student's self-reported beliefs about their math ability or overall GPA scores that were not specific to math were excluded. Third, if a study tested an intervention, we included effect sizes from experimental groups only if data were available for both math anxiety and math achievement *prior* to the intervention. For experimental study control groups, effect sizes from assessments measured before and after the intervention were included.

As a fourth inclusion criterion, we chose to examine only studies published in the English language to reduce potential errors in translation or interpretation. A fifth inclusion criterion was that the achievement and anxiety measures had to be collected and matched by participant and not be collected on separate groups of people (e.g., they could not have math achievement for teachers and math anxiety for students). The sixth, and final, inclusion criterion was that correlational studies were to be included even if they reported on longitudinal data. Correlation coefficients from longitudinal studies with up to two time points were obtained between time point (i.e., time 1 math anxiety with time 1 math achievement, time 1 math anxiety with time 2 math achievement, etc.). Correlation coefficients from longitudinal studies with more than two time points were obtained for each time point separately, rather than for a composite of all time points or between each and every time point (e.g., for three time points, we coded three correlations: time 1 math anxiety with time 1 math achievement, time 2 math anxiety with time 2 math achievement, and time 3 math anxiety with time 3 math achievement).

Coding Procedures and Included Studies

Figure 1 displays a flow chart of the article selection process. The two database searches yielded a total of 1556 relevant documents. We excluded 293 repeated titles, making a final count of 1263 independent documents found through the initial database search. These documents were then subject to close review using the previously outlined inclusion criteria. At each round, questions regarding coding specific articles were discussed as a group through a private, online messaging system and through ad hoc meetings as needed, with the first and second authors resolving any questions unanimously. Training for each round of coding consisted of reviewing the inclusion criteria as a group prior to coding articles and answering any questions that arose until all criteria were well understood.

In Round 1 of narrowing down a final study sample, the first four authors reviewed the study titles and abstracts obtained from the online database search and separated these articles into *yes*, *no*, and *maybe* categories based on inclusion criteria. During Round 1, we excluded the 658 articles that were coded *no*, included the 266 articles that were coded *yes*, and determined that the inclusion of the remaining 339 *maybe* documents was unclear and subject to further inspection in Round 2.

Round 2 consisted of reviewing full-text documents separately for each of the articles identified as *maybes* from Round 1 and categorizing them into *yes* or *no* categories, again based on inclusion criteria. We split the articles so that each article was coded by two coders selected from the first four authors. If the two coders' category choices did not match for an article, these articles were discussed at a roundtable discussion among the first four authors to determine whether or not the study was eligible to be included, using the abstract and full text of the article to make the decision. Out of the 339 articles subject to Round 2, we excluded 192 studies and included 147 studies.

The 413 included articles from Round 1 and Round 2 were coded for descriptive information and information for moderation analyses during Round 3. The following study information from included studies in Rounds 1 and 2 were entered into a Qualtrics survey: correlation coefficients, sample size, gender, race/ethnicity, country, age and grade level, teacher sample, low math ability sample, math anxiety scale, math assessment type, and math content area. These studies were divided between all six authors, all of whom attended a 1-hour training session to learn how to extract the necessary information for each relevant variable prior to coding. In this round, we further excluded 86 studies. Out of the remaining 327 studies that were included and coded during Round 3, 128 studies reported at least 1 correlation coefficient that could be used in this meta-analysis.

The remaining 199 studies did not include the necessary correlation coefficient(s) and were subject to Round 4, where authors were emailed to request correlation information. Corresponding authors of specific studies were contacted by email by the first or second author. During Round 4, we received responses with the information that we needed from authors for 69 of these studies (35%). We excluded the remaining 130 studies from the 199 studies subject to Round 4 because we were unable to obtain the effect size information needed for inclusion.

Thus, overall, the two online database search waves yielded 197 relevant studies to include in this meta-analysis. The second search technique of emailing the CDS listserv yielded information from 26 unpublished data sets and manuscripts. In total, we included 223 studies in the present meta-analysis.

Inter-rater reliability. Twenty percent of the studies included in Round 3 were selected to be double-coded and split between all six coders. The index of agreement rate was calculated for all data extracted by coders who double-coded the article for the inclusion variable, the number of effect sizes, correlation, sample size, gender, race/ethnicity, country, grade level, teachers, students with low math ability, math anxiety scale (separate for child, adolescent/adult, and scale topic), components of math anxiety, math achievement scale, and math content.

We first calculated the agreement rate for the inclusion variable that indicated whether the coder decided to include the study in our sample, based on our inclusion criteria. We then calculated the agreement rate for the number of effect sizes that each coder decided was pertinent from each study. If coders disagreed on the inclusion variable, the study was not included in the agreement rate calculation for the number of effect sizes and moderator variables. Finally, we calculated the agreement rate for each of the moderator variables, based on the final codes that these originally entered codes would have been categorized into for the moderator analyses (see Coding Procedures section). If coders disagreed on the number of effect sizes, we only coded the agreement rate for moderator variables for the effect sizes that overlapped between the coders. Because we had different pairs of raters selected from six possible raters code a random subset of these studies, agreement rate was calculated for each pair of raters (15 possible pairs) and averaged across them for each variable.

The average agreement rate for each variable is reported in Table S1. The average agreement rate was 91% for the inclusion variable, 75% for the number of effect sizes, 85% for the correlation coefficient, and 72% for the sample size. Average agreement rates for the moderator variables ranged from 84% to 100%, with an average of 94.8%. To ensure accurate coding of variables from included studies, most included study variables were checked for accuracy by another independent coder or verified by the first author.

Demographic information. For each effect size, demographic and measure information were recorded in an online Qualtrics survey and then coded for the moderator analysis into particular categories. The coding scheme is outlined below.

Gender. Gender was entered as the percentage of males reported in the sample for each effect size. If gender information was not available in the document, gender was entered as not reported. Reported gender information was then coded into two categories: 1) samples made up of 100% male participants (k = 38) and 2) samples made up of 100% female participants (k =

52). Any samples with greater than 0, less than 100%, or not reported male percentages were not included in the gender moderator analysis (k = 657).

Race/ethnicity. Race/ethnicity was entered as whether the sample associated with each effect size consisted of 75% or more 1) White, 2) Black, 3) Hispanic, or 4) Asian participants, 5) whether the sample consisted of a racially or ethnically diverse group (i.e., no race or ethnicity was more than 75% of the sample), or 6) whether the racial or ethnic breakdown of the sample was not reported. From this initial coding scheme, we found few effect sizes that consisted of primarily Black (k = 1), Hispanic (k = 1), or Asian participants (k = 42). We also found that a large percentage of the effect sizes that had reported race/ethnicity information were from the United States (75%), and that all except one of the Asian samples were from Asia. Thus, to reduce potential confounds related to country, we only included effect sizes for samples from the United States in the race/ethnicity moderator analysis. We ended up coding our race/ethnicity variable into two categories: 1) effect sizes with samples consisting of 75% or more White participants (k = 104) and 2) effect sizes with samples consisting of less than 75% White participants (k = 72). Any effect sizes without race/ethnicity information reported were not included in the race/ethnicity moderator analysis (k = 571).

Country. Country information was entered as either the country or countries reported by the paper for the sample for each effect size or as not reported if country information was not available. There were 52 countries represented (see Table S2 for individual country correlations), and 23 out of these 52 countries (44.2%) had only k=1 (i.e., only one effect size represented the relation for that one country). Thus, we grouped countries according to their respective continent. We will refer to the "country" moderator as the "continent" moderator when describing our analyses in the remainder of the paper. We had effect sizes representing samples from six continents: North America (*k* = 389), South America (*k* = 26), Europe (*k* = 204), Asia (*k* = 103), Africa (*k* = 11), and the geographic region of Oceania, which includes the countries of Australia and New Zealand (*k* = 8). Samples that did not report country information were not included in the continent moderator analysis (*k* = 6).

To account for the variation in cultures among the many countries within these continents, we conducted supplemental moderator analyses by country or region for each continent. North America, South America, Oceania, and Africa each had a small enough number of countries to compare at the country level. However, Asia and Europe were represented by effect size estimates from a large number of countries (i.e., Asia = 16 countries; Europe = 26 countries). Thus, we tested region as a moderator. Asia was divided into five regions (i.e., North, South, East, West, Southeast; Pariona, 2018) and Europe into four regions (i.e., North, South, East, West; Nag, 2018). We have included a figure of the overall effect sizes for these Asian and European regions (as well as the other continents) in Figure S1. Supplemental moderator analyses for each continent and region, separately, are presented in Table S3 and pairwise comparisons for significant moderators are presented in Table S4.

Grade level. Grade level(s) (i.e., year in school) of the sample for each effect size was selected from one or more of the following choices: kindergarten, grade 1, grade 2, grade 3, grade 4, grade 5, grade 6, grade 7, grade 8, grade 9, grade 10, grade 11, grade 12, community college students, undergraduate students, graduate students, non-student adults, or not reported. Mean age, standard deviation of age, minimum age, and maximum age of each sample were also recorded if reported in the study.

For samples with no reported grade level but with a reported age, we estimated the grade according to the average compulsory age for students entering into each grade from the United

States, based on the mean age or the highest category for the range of age if reported (Education Commission of the States, 2018). For samples that included participants from two grades across multiple categories (e.g., grades 5 and 6) we first estimated the grade based on mean age if available. If mean age was not reported and samples were from consecutive grades (i.e., grades 8 and 9), we coded the sample into the category for the highest grade of the two. If mean age was not reported and the samples were from two nonconsecutive grades (e.g., grades 6 and 9), we coded the sample into the category for the average grade rounded up (e.g., rounded up to grade 8 from grade 7.5). If more than two consecutive grades were reported with an odd number of grades, and several of them overlapped across multiple groups (e.g., grades 6 through 10), we first estimated the grade based on mean age, if available. If the mean age was not reported, a mean grade was calculated based on the median grade of the total grade range reported, and subsequently coded into the grade category in which that median grade was included (e.g., samples with students in grades 7 through 9 were calculated to be in grade 8 and coded as being in the grade category for grades 6 through 8). If more than two grades were reported that were not consecutive (e.g., grades 7, 8, and 10), the average grade was taken, rounded to the closest integer, and coded into the corresponding category (e.g., the average of grades 7, 8, and 10 is grade 8.33 and would be rounded to grade 8 and would fall under the category for grades 6 through 8). For those samples that included students in an even number of multiple, consecutive grade levels that spanned across multiple categories, we coded them into the higher of the middle categories (e.g., samples with students in grades 7 through 10 were coded into the high school category because grade 9 is high school).

There were no samples of kindergarten participants. For our analysis, we coded grade levels into six broader categories: (1) grades 1 through 2 (early elementary; k = 68), (2) grades 3 through 5 (late elementary; *k* = 89), (3) grades 6 through 8 (middle/junior-high school; *k* = 116), (4) grades 9 through 12 (high school or pre-university; *k* = 99), (5) undergraduate and graduate students (postsecondary; *k* = 355), and (6) non-student adult samples (*k* = 20).

Teachers. Effect sizes were coded as representing teacher samples if the study reported that the sample was made up of pre-service or practicing teachers (*k* = 58). We compared the average effect size obtained with teacher samples to the average effect size obtained for non-teacher samples (*k* = 689).

Students with low math ability. If the study reported that the authors selected a complete sample based on having low math ability, we coded them as such (*k* = 18). We compared effect sizes of selected samples with low math ability to effect sizes for samples not selected based on ability level (*k* = 729).

Measures information.

Math anxiety scale. Math anxiety measures were categorized in three different ways. Table 1 lists definitions and examples of each of these three categorizations for math anxiety scale. We first categorized math anxiety scales based on whether they were originally developed to assess children's math anxiety. Child math anxiety scales were coded into six categories: 1) Math Anxiety Rating Scale – Elementary (MARS-E; *k* = 42; Suinn, Taylor, & Edwards, 1988), 2) Scale for Early Mathematics Anxiety (SEMA; *k* = 19; Wu et al., 2012), 3) versions of the Math Anxiety Scale for Young Children (MASYC; *k* = 22; Harari et al., 2013; Ganley & McGraw, 2016), 4) Children's Math Anxiety Questionnaire (CMAQ; *k* = 36; Ramirez et al., 2013), 5) Math Anxiety Questionnaire (MAQ; *k* = 11; Thomas & Dowker, 2000), and 6) all other math anxiety scales made for children (*k* = 25). For this variable, any math anxiety scale that was not developed to assess math anxiety in children was coded as missing and excluded from the moderator analysis for children's math anxiety scales (*k* = 592).

We then categorized math anxiety scales based on whether they were originally developed to assess adolescent and postsecondary/adult math anxiety. Ten categories were coded for adolescent and postsecondary/adult math anxiety measures: 1) Math Anxiety Rating Scale (MARS) and MARS-based measures (*k* = 197; e.g., Hopko et al., 2003; Richardson & Suinn, 1972), 2) one-item math anxiety measures (*k* = 18; e.g., Núñez-Peña et al., 2014), 3) Fennema Sherman Math Anxiety Scale (FSMAS; *k* = 44; Fennema & Sherman, 1976), 4) MARS-based measures created for adolescents (*k* = 8), like the MARS-Adolescents (MARS-A; Suinn & Edwards, 1982), 5) the math anxiety scale used by the Programme for International Student Assessment (PISA; *k* = 56), 6) Achievement Emotion Questionnaire Math Anxiety Subscale (AEQ; *k* = 7; Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011), 7) Math Anxiety Scale created by Betz (MAS; *k* = 25; Betz, 1978), 8) Math Anxiety Scale created by Meece (MAS; *k* = 15; Meece, 1981), 9) Math Anxiety Scale created by Bai and colleagues (*k* = 19; Bai, Wang, Pan, & Frey, 2009), and 10) all other measures (*k* = 123). For this variable, any math anxiety scale that was specified to assess math anxiety in children was coded as missing and excluded from the moderator analysis for adolescent and adult math anxiety scales (*k* = 235).

Math anxiety topic. We also created a third math anxiety scale variable where we coded whether the anxiety topic assessed was math or statistics specific. For this variable, if the anxiety scale explicitly stated that the anxiety topic being assessed was for statistics then the scale was coded as statistics anxiety (*k* = 80). If the scale did not specify that it assessed anxiety in the subject of statistics, then it was coded as math anxiety (*k* = 667).

Components of math anxiety. Table 1 lists definitions and example items for four of the most commonly measured components of math anxiety: worry, emotionality, math evaluation anxiety, and math learning anxiety. This moderator was coded into six categories that differentiated between these four components: 1) worry (k = 14), 2) emotionality, including affect, dread, and negative reactions (k = 7), 3) both worry and emotionality (k = 11), 4) math evaluation anxiety, including test and examination anxiety (k = 55), 5) math learning anxiety, including class/course anxiety (k = 35), and 6) both math evaluation and math learning anxiety (k = 120). If the study explicitly specified that the correlation was between one of these specific components of math anxiety and math achievement, then it was coded in its respective category. In addition, widely-used scales that had previous factor analyses conducted, like the MARS (Richardson & Suinn, 1972) with factor analysis done by Rounds & Hendel (1978) and the AMAS (Hopko et al., 2003), were coded using the factor structure found in the construct validation studies, unless a different factor structure was found and stated for a newer individual study or if the effect size was for one of the multiple components. If the effect size did not explicitly specify that the math anxiety scale was assessing one of these categories or if it was measuring categories that overlapped with other categories that were not included (e.g., math performance adequacy anxiety) then it was excluded from the moderator analysis (k = 505).

Math assessment. Table 1 lists definitions and examples of each category for type of math assessment. Math assessments were coded into five categories that characterized the type of assessment: 1) standardized criterion-referenced or norm-referenced assessment used for high-stakes testing (k = 56), 2) standardized assessment used for research purposes (k = 322), 3) non-standardized researcher-made or other assessments (k = 166), 4) course grades (k = 113), and 5) class exam grades (k = 90). If a math assessment contained a composite score made up of several measures that could be coded into one of the five categories, that measure was coded into the appropriate category. If assessments overlapped across more than one category, these effect sizes were coded in the “non-standardized researcher-made or other assessments” category.

Math content. We adapted the math content category definitions from Peng, Namkung, Barnes, & Sun (2016) as a model for coding math content in the current meta-analysis. Table 1 provides definitions and examples of these categories. The content of the math assessment was determined from each article and initially coded into whichever content area(s) they measured. Effect sizes were then used for the moderator analysis if the assessment measured achievement in only one content area: 1) approximate number system (k = 14), 2) basic number knowledge (k = 30), 3) whole number calculation (k = 113), 4) word problem solving (k = 20), 5) fractions, decimals, or percentages (k = 10), 6) geometry (k = 9), 7) algebra (k = 34), and 8) statistics, data analysis, and probability (k = 105). If the math assessment assessed multiple content areas, the effect size was excluded from the math content moderator analysis (k = 412).

Data Analysis

Overall average effect size. We used Pearson’s r correlation coefficient as the effect size for the present meta-analysis. Under the assumption that the effect size would be based on variables using scales that were continuous rather than rank-ordered or categorical, we requested Pearson correlation coefficients from authors who reported Spearman’s correlation coefficient. Pearson correlation coefficients were converted to Fisher’s Z-scores to approximate a normal distribution of the population effect sizes (Cohn & Becker, 2003).

Due to varying sample and measure characteristics used to assess math anxiety and math achievement, the overall average effect size model was fitted as a random-effects model. The sample of included effect sizes was considered to come from a universal number of populations instead of one single population; therefore, the true effect size that a study estimates is considered to be random and made up of the true estimate plus the sampling error variance and between-studies variance. Once the true effect size estimate was calculated, we transformed the overall Fisher's z-score back to a Pearson's *r* correlation coefficient for interpretation and reporting purposes.

Effect sizes for samples with multiple reported correlation coefficients (i.e., dependent samples) violate the assumption of independent samples; therefore, we conducted multilevel meta-analyses to model the nested structure of the data. This technique accounts for correlations between the dependent effect sizes and models the Level-1 (effect size) and Level-2 (sample) correlations (Maas & Hox, 2004). To conduct these multilevel meta-analyses, the metafor package from the statistical program R was used with the restricted maximum likelihood estimation method (Viechtabauer, 2010).

Heterogeneity of effect sizes. To determine if there was a significant amount of unexplained between-study heterogeneity (i.e., large between-samples variance beyond within-sample variance) in the combined estimate of overall effect size and whether it would be appropriate to test for moderators to account for this unexplained heterogeneity (Cooper, Hedges, & Valentine, 2009), we calculated the *Q*-statistic and its significance. This statistic tests the null hypothesis that the study effect sizes are estimates from a single population against the alternative hypothesis that the observed variance in study effect sizes is greater than would be expected by chance if all studies shared a common population effect size (Cochran, 1954). In addition, we also calculated the associated I^2 -statistic. This is a descriptive statistic that indicates how much of the variability across studies is due to heterogeneity as opposed to chance due to sampling error (Higgins & Thompson, 2002).

Analyzing variability in effect sizes. We tested whether the amount of unexplained variance across the effect sizes was attributable to specific demographic or measure characteristics from the sample of studies. We used an ANOVA framework and performed separate omnibus tests for each moderator variable to determine whether there were significant differences in the size of the effect sizes between the groups in each moderator. If the omnibus test was significant, we tested for further significant differences between effect sizes for each subgroup of the moderator using pair-wise comparisons for every possible pair of subgroups. To reduce the false discovery rate, we applied the Benjamini-Hochberg correction to each group of pair-wise comparisons (Benjamini & Hochberg, 1995). Finally, to obtain overall effect sizes for each subgroup within a moderator, we conducted random-effects multi-level models for each subgroup using datasets that only contained effect sizes for the specific subgroup.

Publication bias. We used several indices to assess publication bias. First, we tested whether there were significantly different correlations for effect sizes that came from published studies compared to unpublished work. We categorized the moderator variable of publication status into two groups, 1) published studies ($k = 520$) and 2) unpublished work including theses, dissertations, and unpublished studies ($k = 227$).

Next, we checked whether the effect sizes included in the meta-analytic sample are distributed symmetrically around the average overall effect size. This method to assess potential publication bias provides a visual and statistical test that detects the difference in effect sizes from large study samples compared to effect sizes from small study samples. Small study samples are more likely to be published only if they produce positive results, compared to large study samples that are more likely to be published regardless of the result (Sterne & Harbord, 2004). We created and visually inspected a funnel plot, which graphs each effect size by its standard error in a scatter plot, which is an indicator of the sample size of the study. We expect the funnel plot to show an even distribution of the effect sizes around the true population effect size, with effect sizes getting more precise and closer to the true effect size as the sample size increases. The funnel plot would indicate publication bias against small studies if it is visually evident that negative results (i.e., weak or positive correlations between math anxiety and math achievement) are associated with large standard errors (i.e., lower half of plot).

We also statistically tested for asymmetry by conducting Egger's test, a meta-regression analysis that estimates effect size precision (i.e., the standard error) as a predictor of the correlation coefficient, in a multi-level model (Egger, Smith, Schneider, & Minder, 1997). If the meta-regression analysis is significant, it indicates the intercept of the dependent variable (i.e., the correlation coefficient) is significantly different from zero, suggesting that the effect sizes are not distributed evenly around the true population effect size.

Finally, we also used the trim-and-fill method on the effect sizes in the meta-analytic sample. The trim-and-fill method determines the adjusted estimate of the average overall effect size and its significance after filling in sparse areas of the funnel plot and removing outliers (Duval & Tweedie, 2000). The trim-and-fill method is an indicator of how biased an overall effect size is from the current meta-analytic sample compared to the effect size from a sample that may more accurately account for the missing effect sizes that may not have been published and therefore are not represented on the funnel plot (i.e., file drawer problem; Rosenthal, 1979).

Results

Overall Average Correlation Between Math Anxiety and Math Achievement

The 223 studies included in the present meta-analysis consisted of 747 correlation coefficients from 332 independent samples with approximately 385,441 individual participants (see supplemental materials for coded information for each effect size [Tables S5 and S6] and references of included studies). Overall, the average correlation between math anxiety and math achievement was small-to-moderate, negative, and significant ($r = -.28$, 95% Confidence Interval [CI] [-.29, -.26]). As indicated by the Q-statistic and I^2-statistic, there was a significant amount of unexplained variance across the range of effect sizes included in the calculation of the overall average effect size ($Q = 7784.61$, $p < .0001$, $df = 747$; $I^2 = 90.42$), suggesting that these effect sizes did not come from the same population and validating our use of a random-effects model.

Moderation Effects of Demographic and Measure Characteristics

Next, we conducted moderator analyses to examine potential demographic or measure characteristics that might explain the variation found in the relation between math anxiety and math achievement. Average effect sizes for subgroups within each moderator were negative and statistically significant, with the exception of the average effect size for the approximate number system subgroup within the math content moderator ($r = -.09$, 95% CI [-.18, .005], $p = .06$). Table 2 shows F-test results, Q-statistics, variance explained by Level-1 and Level-2 for each moderator analysis, and I^2-statistics. Even after accounting for differences in the subgroups within each moderator, a significant amount of heterogeneity still remained in the overall effect size for each moderator analysis. P-values obtained from pairwise comparisons for subgroups of significant moderators were interpreted based on Benjamini-Hochberg adjusted cutoffs. We report comparisons that remained significant after the Benjamini-Hochberg correction was taken into account.

Moderation Effects of Demographic Characteristics

Gender. Figure 2 contains a forest plot for effect sizes across demographic characteristics. The subgroups for testing gender as a moderator were samples with 100% male participants (k = 38; r = -.24, 95% CI [-.29, -.17]) and those with 100% female participants (k = 52; r = -.28, 95% CI [-.34, -.23]). The analysis indicated that the average effect size for males was not significantly different from the average for females (F[1, 88] = 1.19, p = .28).

Race/ethnicity. The subgroups for testing race/ethnicity as a moderator were samples with greater than 75% White participants (k = 72; r = -.26, 95% CI [-.30, -.22]) and samples with less than 75% White participants (k = 104; r = -.24, 95% CI [-.28, -.21]). The moderator analysis indicated that the average effect sizes for these two groups did not significantly differ from one another (F[1, 174] = 0.28, p = .60).

Continent. The subgroups for testing continent as a moderator were North America (k = 389; r = -.26, 95% CI [-.29, -.24]), South America (k = 26; r = -.20, 95% CI [-.37, .00]), Europe (k = 204; r = -.27, 95% CI [-.31, -.24]), Asia (k = 103; r = -.31, 95% CI [-.36, -.25]), Africa (k = 11; r = -.25, 95% CI [-.31, -.19]), and Oceania (k = 8; r = -.38, 95% CI [-.55, -.18]). The omnibus test for the continent moderator analysis was not statistically significant (F[5, 735] = 1.56, p = .17), indicating that there were no statistically significant differences in the relations between math anxiety and math achievement between samples from each of the six continents. The results of the supplemental continent moderator analyses and pairwise comparisons are reported in Tables S3 and S4.

Grade. The subgroups for testing grade level as a moderator were Grades 1 and 2 (k = 68, r = -.26; 95% CI [-.31, -.23]), Grades 3 through 5 (k = 89, r = -.20; 95% CI [-.25, -.14]), Grades 6 through 8 (k = 116, r = -.30; 95% CI [-.35, -.26]), Grades 9 through 12 (k = 99, r = -.34; 95% CI [-.36, -.31]), undergraduate and graduate students (k = 355, r = -.24; 95% CI [-.27, -.22]), and non-student adult samples (k = 20, r = -.32; 95% CI [-.39, -.25]). The omnibus test for the grade level moderator analysis was statistically significant (F[5, 741] = 6.64, p < .001), indicating that at least one of the subgroups within the grade level moderator variable is statistically significantly different from at least one of the other subgroups.

Pairwise comparisons indicated several statistically significant differences between grade levels in the average correlation between math anxiety and math achievement (Table 3). Students in Grades 1 and 2 demonstrated a statistically significantly lower magnitude correlation than students in Grades 9 through 12 (b = -.07, p = .02). The average correlation for students in Grades 3 through 5 was significantly weaker than the average correlation between math anxiety and math achievement for students in Grades 6 through 8 (b = -.11, p = .004), Grades 9 through 12 (b = -.14, p < .001), and non-student adults (b = -.14, p = .02). In addition, the average correlation between math anxiety and math achievement for students in Grades 6 through 8 (b = .07, p = .01) and Grades 9 through 12 (b = .10, p < .001) were significantly stronger than the average correlation found for postsecondary student samples.

We also were interested in further examining this relation to determine whether the grade level differences in the relation between math anxiety and math achievement were evident across all math content areas or just specific math content areas. We conducted post-hoc grade level moderator analyses separately for samples with achievement measures that assessed only one math content area (Table S7). We found that relations between math anxiety and specific math content areas were mostly similar across grade levels except for assessments measuring basic number knowledge ($F[3, 26] = 6.42$, $p = .002$) and algebra ($F[3, 30] = 3.26$, $p = .04$). Pairwise comparisons, shown in Table S8, indicated that students in Grades 1 and 2 ($r = -.40$, $p = .004$) showed a significantly stronger correlation between math anxiety and basic number knowledge than did students in Grades 3 through 5 ($r = .0009$, $p = .99$; $b = .40$, $p < .001$) and postsecondary school students ($r = -.12$, $p = .23$; $b = .29$, $p = .03$). Students in Grades 3 through 5 had weaker relations between math anxiety and basic number knowledge than did students in Grades 6 through 8 ($r = -.17$, $p = .12$; $b = -.17$, $p = .001$). The relation between math anxiety and algebra knowledge was significantly weaker in magnitude for postsecondary school students ($r = -.17$, $p <.001$) compared to the relation for students in Grades 6 through 8 ($r = -.32$, $p = .06$; $b = .21$, $p = .01$) and Grades 9 through 12 ($r = -.40$, $p = .18$; $b = .29$, $p < .001$).

Teachers. Figure 3 contains a forest plot for effect sizes for subgroup analyses for teacher and low ability groups. The subgroups for testing teacher samples as a moderator were pre-service and practicing teacher samples ($k = 58$, $r = -.31$; 95% CI [-.37, -.24]) and non-teacher samples ($k = 689$, $r = -.27$; 95% CI [-.29, -.26]). The omnibus test for the teacher moderator analysis was not statistically significant ($F[1, 745] = 0.59$, $p = .44$), indicating that there was no statistically significant difference in the relations between math anxiety and math achievement for pre-service and practicing teacher samples compared to non-teacher samples.

Students with low math ability. The subgroups for testing students with low math ability as a moderator were samples selected for low math ability ($k = 18$, $r = -.09$; 95% CI [-.17, -.004]) and samples not selected for low math ability ($k = 729$, $r = -.28$; 95% CI [-.30, -.26]). The moderator analysis for low math ability samples was statistically significant ($F[1, 745] = 6.29$, $p = .01$), indicating that the correlation coefficient for the relation between math achievement and math anxiety for samples selected for low math ability was significantly weaker than the relation between math achievement and math anxiety for samples not selected for low math ability (b = -.21, p = .01; Table 3).

Moderation Effect of Measure Characteristics

Math anxiety scales. Figure 4 contains a forest plot for effect sizes across math anxiety scales and components of math anxiety.

Child math anxiety scales. The subgroups within the child math anxiety scales moderator variable were the MARS-E (k = 42, r = -.24, 95% CI [-.34, -.14]), SEMA (k = 19, r = -.23. 95% CI [-.41, -.03]), MASYC (k = 22, r = -.24, 95% CI [-.30, -.16]), CMAQ (k = 36, r = -.26, 95% CI [-.34, -.20]), MAQ (k = 11, r = -.10, 95% CI [-.16, -.04]), and other child math anxiety scales (k = 25, r = -.34, 95% CI [-.44, -.23]). The omnibus test conducted for the six subgroups within child math anxiety scales was not statistically significant (F[5, 149] = 1.26, p = .28), indicating that there were no statistically significant differences in the relations between math anxiety and math achievement across different types of math anxiety scales typically used for children.

Adolescent and adult math anxiety scales. The subgroups within the adolescent and adult math anxiety scales moderator variable were the MARS (k = 197, r = -.23; 95% CI [-.25, -.20]), one-item (k = 18, r = -.18; 95% CI [-.27, -.09), FSMAS (k = 44, r = -.37; 95% CI [-.43, -.31]), MARS-A (k = 8, r = -.31; 95% CI [-.49, -.11]), PISA (k = 56, r = -.34; 95% CI [-.36, -.31]), AEQ-MA (k = 7, r = -.39; 95% CI [-.52, -.24]), MAS-Betz (k = 25, r = -.35; 95% CI [-.44, -.25]), MAS-Meece (k = 15, r = -.24; 95% CI [-.32, -.16]), MAS-Bai (k = 19, r = -.28; 95% CI [-.34, -.22]), and other scales (k = 123, r = -.28; 95% CI [-.32, -.24]). The omnibus test performed for the ten categories within adolescent and adult math anxiety measures was statistically significant (F[9, 502] = 6.87, p < .001), indicating that at least one of the subgroups within the adolescent and adult math anxiety moderator variable is statistically significantly different from at least one of the other subgroups.

Results are listed in Table 4 for pairwise comparisons between subgroups of adolescent and adult math anxiety scales. MARS-based scales were found overall to have a significantly weaker relation with math achievement than did the FSMAS (b = -.16, p < .001), PISA (b = -.12, p < .001), the AEQ-MA (b = -.18, p = .003) and MAS-Betz (b = -.14, p = .003). Similarly, one-item math anxiety scales were found to have an average correlation coefficient with math achievement that was significantly weaker than the relation between math achievement and FSMAS (b = -.21, p = .001), PISA (b = -.16, p < .001), and the AEQ-MA (b = -.39, p < .001).

Anxiety scale topic. The subgroups within the anxiety scale topic moderator were math anxiety (k = 667, r = -.28, 95% CI [-.30, -.26]) and statistics-specific anxiety (k = 80, r = -.17, 95% CI [-.24, -.11]). The moderator analysis for anxiety scale topic was statistically significant (F[1, 745] = 12.14, p = .001), indicating that the correlation coefficient for the relation between math achievement and anxiety scales assessing math anxiety was significantly stronger than the relation between math achievement and scales assessing statistics-specific anxiety (b = .09, p = .001).

We were also interested in determining whether the stronger relation between math achievement and math anxiety held even when examining only statistics-specific achievement. We conducted two additional post-hoc anxiety scale topic moderator analyses, one using effect sizes that only assessed statistics content knowledge and the other analysis using effect sizes that assessed everything except statistics content (Table S7). We found that the moderator did not remain statistically significant for achievement assessments of only statistics knowledge (F[1, 103] = 0.14, p = .71), indicating that math anxiety (r = -.23, p <.001, k = 49) and statistics anxiety (r = -.19, p < .001, k = 56) were similarly related to achievement in statistics. Additionally, we found that when the effect sizes consisted of scales assessing other types of math achievement, the moderator was still significant (F[1, 640] = 20.76, p < .001), with nonstatistics math content having a stronger relation with math anxiety (r = -.29, p < .001, k = 618) compared to statistics anxiety scales (r = -.10, p = .005, k = 23).

Components of math anxiety. The subgroups within the components of math anxiety were worry (k = 14, r = -.37, 95% CI [-.50, -.23]), emotionality (k = 7, r = -.35, 95% CI [-.45, -.24]), both worry and emotionality (k = 11, r = -.24 95% CI [-.37, -.10]), math evaluation anxiety (k = 55, r = -.21, 95% CI [-.24, -.16]), math learning anxiety (k = 35, r = -.28, 95% CI [-.35, -.21]), and both math evaluation and learning anxiety (k = 120, r = -.22, 95% CI [-.24, -.19]). The omnibus test performed for the six categories within components of math anxiety was statistically significant (F[5, 236] = 3.02, p = .01), indicating that at least one of the subgroups is statistically significantly different from at least one of the other subgroups. Results for pairwise comparisons (Table 5) indicated that the relation between math achievement and the worry component of math anxiety was stronger than the relation between math achievement and math evaluation anxiety (b = .18, p = .002) and between math achievement and both math evaluation and learning anxiety (b = .17, p = .001). The relation between math achievement and emotionality (b = .15, p = .003) and between math achievement and math learning anxiety (b = .08, p = .01) was also stronger than the relation between math achievement and both math evaluation and learning anxiety.

Math assessments. Figure 5 contains a forest plot for effect sizes across math assessments and content area. The subgroups within the math assessment moderator were high-stakes standardized math tests (k = 56, r = -.26, 95% CI [-.30, -.23]), standardized measures for research purposes ($k = 322$, $r = -.29$, 95% CI [-.31, -.27]), researcher-made and non-standardized measures for research ($k = 166$, $r = -.29$, 95% CI [-.34, -.25]), course grades in math classes ($k = 113$, $r = -.27$, 95% CI [-.31, -.23]), and exam grades on math assessments ($k = 90$, $r = -.20$, 95% CI [-.24, -.15]). The omnibus test for the math assessment moderator was statistically significant ($F[4, 742] = 2.34$, $p = .054$) and pairwise comparisons for this moderator are shown in Table 6. Specifically, the overall relation found between math anxiety and math exam grades was weaker than the relation between math anxiety and standardized assessments used for research ($b = -.08$, $p = .002$) and between math anxiety and non-standardized research measures and other math assessments ($b = -.09$, $p = .01$).

Math content. The subgroups within the math content area moderator were approximate number system ($k = 14$, $r = -.09$, 95% CI [-.18, .005]), basic number knowledge ($k = 30$, $r = -.16$, 95% CI [-.25, -.07]), whole number calculation ($k = 113$, $r = -.23$, 95% CI [-.25, -.20]), word problem solving ($k = 20$, $r = -.27$, 95% CI [-.40, -.15]), fractions, decimals, and percentages ($k = 10$, $r = -.37$, 95% CI [-.52, -.20]), geometry ($k = 9$, $r = -.32$, 95% CI [-.46, -.16]), algebra ($k = 34$, $r = -.23$, 95% CI [-.30, -.15]), and statistics knowledge ($k = 105$, $r = -.23$, 95% CI [-.28, -.17]). The omnibus test for the math content area moderator analysis was not statistically significant ($F[7, 327] = 1.40$, $p = .21$), indicating that there were no statistically significant differences in the relations between math anxiety and math assessments in different math content areas.

Publication bias

The moderator analysis for publication status was statistically significant ($F[1, 745] = 12.02$, $p < .001$). There was a significantly stronger negative correlation between math anxiety and math achievement reported in published studies ($k = 520$, $r = -.29$, 95% CI [-.32, -.27]) than for unpublished studies ($k = 227$, $r = -.23$, 95% CI [-.25, -.21]).

Visual inspection of the funnel plot of the effect sizes by their standard errors (black dots in Figure 6), with higher standard errors at the bottom of the plot, indicated that the spread of the effect sizes was not perfectly symmetrical. Many of the effect sizes were located around and just to the right of the line denoting the overall average correlation ($r = -.28$), suggesting that most of the effect sizes in the meta-analytic sample represent reporting small-to-moderate negative effect sizes from studies with various sample sizes. A statistically significant Egger test ($z = 2.59$, $p = .01$) confirmed the presence of funnel plot asymmetry. The potential missing studies in the left half of the plot, as shown by the sparseness of effect sizes in that area compared to the right half, may indicate higher magnitude negative effect sizes from samples of all sizes are missing from our meta-analytic sample. The trim-and-fill analysis indicated that 129 effect sizes (white dots in Figure 6), primarily clustered in the left half of the asymmetrical plot, are potentially missing and needed to fill in the sparse areas of the funnel plot. The result of the trim-and-fill analysis suggested that, after adjusting the funnel plot to become symmetrical, the adjusted overall correlation coefficient would remain statistically significant and similar in magnitude to the original overall correlation coefficient ($r = -.29$, $p < .001$).

Discussion

Math achievement and math anxiety have been studied together for more than half a century (Dreger & Aiken, 1957). Previous meta-analyses have provided us with some knowledge about the association between math anxiety and math achievement, specifically that the association is negative and small-to-moderate, with patterns of high math anxiety often co-occurring with low math achievement (Hembree, 1990; Ma, 1999). Since the publication of previous meta-analyses in the 90s, the trend to study these constructs together has continued to grow. Reviews summarizing the wave of research from more recent years have primarily focused on examining the potential mechanisms behind the association between math anxiety and math achievement (Beilock & Maloney, 2015; Foley et al., 2017), leaving a need for an updated and thorough statistical summary of the work conducted on this relation since the start of the 21st century. Thus, the aims of the present meta-analysis were to 1) calculate an overall average weighted effect size based on recent work on the relation between math anxiety and math achievement and 2) conduct moderator analyses in order to determine whether the magnitude of the correlation differs depending on the demographic characteristics of the sample or the measures used to assess math anxiety or math achievement.

Overall Average Effect Size

We found an overall average correlation of -.28 across all included samples in our meta-analysis, indicating that math anxiety and math achievement tend to have a small-to-moderate negative association. Our findings are similar to the overall average correlation of -.27 found by Ma (1999) and fall within the range of correlations of -.25 to -.40 reported by Hembree (1990). Our results also reveal that there is significant heterogeneity in the spread of effect sizes that estimate the overall relation between math anxiety and math achievement. This suggests that variability in these effect sizes is due to the inclusion of samples that do not represent a homogenous population, supporting our methodological choice to conduct random-effects and mixed-effects models.

Moderators

We found that, after grouping effect sizes by subgroups within our moderators, significant negative relations between math anxiety and math achievement remained for most of our subgroups. We also found there were several significant differences in the size of the relation between subgroups within some moderators. Importantly, although our moderator analyses were able to provide some valuable information about potential sources of variability in the size of the effect sizes for the relation between math anxiety and math achievement, the estimates of heterogeneity for all the moderator analyses indicated that there was still a significant amount of variance left unexplained. These findings suggest that there may be other factors, like different levels of working memory (Ramirez, Chang, Maloney, Levine, & Beilock, 2016) or motivation in math (Wang et al., 2015), or a combination of factors including those not currently incorporated in the present study, that may be able to explain remaining variability found in the correlations included in this meta-analysis. Another important note to consider is that, despite weighting effect sizes by their standard errors and testing moderators of math assessments and anxiety scales, there still may be differences in the relation between math anxiety and math achievement that are due to the inherent differences between large-scale samples with equivalent and standardized measures (such as the PISA) and small-scale studies that use convenience samples and often use researcher-developed measures.

Demographic characteristics as moderators.

Gender, race/ethnicity, and continent. It has been hypothesized in some work that the relation between math anxiety and achievement would be stronger for women than for men (Aiken, 1970), but that has not been found overall in either the current or previous meta-analyses. Specifically, Hembree (1990) found the opposite, that males in grades 5 through 12 demonstrated a stronger correlation between math anxiety and math achievement compared to females in that same age group. Contrary to these findings, we found in the current meta-analysis that the correlations for gender, when broken down by samples with either 100% male or 100% female participants, were similar in strength and magnitude, as did Ma (1999). Previous research has found gender differences in levels of self-reported math anxiety, with greater math anxiety reported by girls than by boys (Devine, Fawcett, Szűcs, & Dowker, 2012). Small gender differences have also been found in math achievement during middle childhood and adolescence, with the slight advantage switching between males and females and depending on the age of the sample and the type of math assessment (Else-Quest, Hyde, & Linn, 2010). Despite these differences in levels of math anxiety and math achievement scores separately, our meta-analytic results based on a pooled, diverse sample of studies, found that the association between math achievement and math anxiety is similar for males and females.

With regard to differences in the math anxiety-math achievement relation among different racial and ethnic groups, we found similar relations for samples from the United States made up of 75% or more White participants and samples that consisted of 75% or less White participants (i.e., majority non-White participants or racially diverse sample). This finding aligns with the results from Ma's (1999) meta-analysis where he found similar magnitude correlations for ethnically homogenous versus ethnically heterogeneous samples. Importantly though, the present moderation analysis of race and ethnicity differences is subject to certain limitations. Specifically, the number of effect sizes from different race and ethnic groups was small and only data from samples within the United States were analyzed. However, given that cultural differences within racial and ethnic groups vary greatly depending on the specific racial and ethnic group being studied (Betancourt & López, 1993), it may be that differences in the relation between math anxiety and math achievement may only arise when looking across a variety of racial and ethnic groups from different countries rather than examining all minority groups from only one country. Thus, future work should examine the relation between math anxiety and math achievement from a variety of racial and ethnic groups from different countries in order to provide insight on the role of specific cultural practices within a specific racial or ethnic group.

The results of the previously untested moderator of the continent of origin of the study sample suggest that there are no significant differences in the strength of the relation between math anxiety and math achievement across the six continents tested in the current paper. Although some work has found that, overall, the correlation tends to be smaller in magnitude for samples from Asian countries (i.e., *r*s = -.12 to -.31) compared to North American and many European countries (i.e., *r*s = -.26 to -.51, Lee, 2009), this was not found to be the case in the current paper when testing for differences in effect size magnitude between continents, rather than between countries. However, as previously noted, cultures and educational systems between the countries within a continent are very different. We do provide some evidence in our supplemental analyses that there are differences in the relation at the country- and region-level within continents, yet many of these overall effect sizes are represented by only one sample. Although there may not be significant differences in the relation between math anxiety and math achievement at the continent-level, there is some support for the idea that the correlation varies depending on the country or region being studied. As such, research to collect more data in a larger number of samples from different countries is needed in order to gain a more precise understanding of where around the globe the relation differs and to further study cultural mechanisms that may be driving these differences.

Grade level. Previous meta-analyses have found significant associations between math anxiety and achievement for students in grades ranging from grade 4 to college level (Hembree, 1990) but no significant differences in the magnitude of the relation based on grade level (Ma, 1999). In the current meta-analysis, we were able to include data from students in grades as early as grade 1 all the way up to samples made up of non-student adults. Our findings support previous work indicating that a significant relation between math anxiety and math achievement exists throughout different development periods, as well as adding that a significant relation exists for samples in early elementary school and beyond formal schooling in adulthood.

The significant differences we did find between grade level categories in the relation between math anxiety and math achievement suggest that the magnitude of the association varies across development. During early elementary school, the relation between math anxiety and achievement is significantly stronger compared to the same relation during high school. However, some research has found that general anxiety, a factor not considered in the present meta-analysis, explains the relation found between math anxiety and math achievement in young children (Dowker et al., 2016; Hill et al., 2016). As such, more work is needed to address and understand the mechanisms driving the stronger relation found between math anxiety and math achievement during early childhood.

Our findings also suggest that the relation between math anxiety and math achievement across grades does not follow a linear trend across development. Specifically, the correlation for students in grades 3 through 5 was significantly weaker than the relation for students in each of the other grade categories, with the exception of grades 1 and 2 and postsecondary students. Our supplemental analyses suggest that the weaker relation could be driven by differences in the relation between math anxiety and basic number knowledge for students in grades 3 through 5 compared to students in grades 1 and 2 and grades 6 through 8 (Tables S7 and S8). Overall, future research should consider the math content area as an important factor that may contribute to grade-level differences, particularly for students in late elementary school, in the math anxiety–math achievement association.

Moving on from late elementary to middle school, we do see a statistically significant increase in the relation between math anxiety and math achievement. Once students reach high school, the relation is found to be significantly stronger than that of the relation during late elementary school. High school students may experience increased pressure to perform well in school while preparing for selection into postsecondary school entry (Clinedinst & Koranteng, 2017), which could explain this increase in the co-occurrence of high math anxiety with low math achievement. Postsecondary school students, on the other hand, demonstrate a weaker relation in comparison to students in earlier development. Students who reach postsecondary education may represent a population of students with higher math achievement that experience less math anxiety as a result of their higher math ability, potentially reducing the strength of the relation between math anxiety and math achievement at that point in development.

Finally, we found that the relation does not disappear for non-student samples. Instead, the magnitude of the correlation is equivalent to the correlation for students in most of the other grade levels, with the exception of postsecondary school students, who demonstrate a weaker relation between math anxiety and math achievement than do non-student adults. This overall finding suggests a need for more research to further understand how the association between math anxiety and math achievement develops from childhood to adulthood.

It is important to note that the grade levels we coded in this study are based on the ages typically included in grade levels within the United States, and therefore these grades may differ internationally. In addition, some samples represented participants across a wide age range spanning across multiple grade level categories, yet we coded these groups into one category that matched the average age.

Teachers. With regard to pre-service and practicing teacher samples, we found that, on average, studies examining these samples reported significant correlations between math anxiety and math achievement. In addition to the significant correlations found for non-student adult samples, these findings further emphasize why it is important to study this relation after high school graduation; clearly, this association is not a phenomenon that develops and then disappears once people have graduated from primary and secondary school. Future work should not only aim to create and implement interventions geared toward math anxiety or math achievement for student samples, but they may also explore the implementation of these interventions to non-student adults and teachers. Furthermore, there is some work suggesting that students majoring in elementary education have higher math anxiety than people in other college majors (Hembree, 1990), and that this math anxiety can influence their students' beliefs and math achievement (Beilock et al., 2010). Importantly, we did not find the relation between math anxiety and math achievement to be significantly different between teacher and non-teacher samples. Though teachers have become a focus of research due to higher levels of anxiety, their anxiety does not appear to be more or less related to their math performance compared to other segments of the population.

Students with low math ability. For the moderator analyses for low math ability samples, we did find a significant difference in the relation between math anxiety and math achievement for samples selected for low math ability compared to those not selected. Specifically, samples selected for low math ability had weaker, although still significant, associations than did samples not selected for low math ability. These findings are contrary to some work extending the deficit model of the relation between math anxiety and math achievement to populations with math learning disabilities (Lai, Zhu, Chen, & Li, 2015; Wu, Wilcutt, Escovar, & Menon, 2014). Instead, we find that, overall, the achievement of samples with low math ability is less related to math anxiety than it is for those samples that represent a wider range of math ability. Of course, it is important to note that the range of math achievement for many of these selected samples is typically restricted due to the cutoffs used for selection, and as such a stronger relation may not be as clear as it is for samples with more variability in their math achievement. In sum, more work needs to be done to better understand the weaker relations found for samples selected for low math ability compared to samples representing a larger range of math ability.

Measure characteristics as moderators.

Math anxiety scales. With regard to the scales used to measure math anxiety, Ma (1999) previously found that the relations with math achievement did not significantly differ when using the MARS compared to a non-MARS measure. However, the 37 studies included in Ma's (1999) meta-analysis represented only six individual math anxiety instruments. A number of new scales to measure math anxiety have emerged since then, and therefore we were able to test for effect size differences between scales that were developed to measure math anxiety separately in children and in adolescents and adults. Although some studies utilized child-, adolescent-, or adult-oriented measures in samples other than the age group they were intended for, creating separate variables for child as well as adolescent and adult anxiety measures allowed us to account for a majority of the confounding effect of age.

Overall, we found that math anxiety had a significant relation with math achievement for all math anxiety scale groups coded in this meta-analysis for children, adolescents, and adults. For the six child math anxiety scales, our results suggested that a similar relation can be expected with math achievement no matter which child math anxiety scale is used.

However, for adolescent and adult math anxiety scales, we found that several measures, specifically the group made up of MARS-based scales and one-item scales, had significantly weaker relations with math achievement than did the PISA math anxiety scale, the Fennema Sherman Math Anxiety Scale (FSMAS), the Achievement Emotion Questionnaire Math Anxiety

Scale (AEQ), and the Math Anxiety Scale by Betz (MAS [Betz]; 1988). On the one hand, the one-item scale may not tap enough into specific math situations (due to only being one item rather than having a range of situations from multiple items) to consistently be associated with math achievement. On the other hand, scales like the original 98-item MARS may have way too many items that may lead to poor data quality and similarly reduce the potential association that math anxiety can have with math achievement. The MARS category in the current paper, however, includes shorter MARS-based measures also, like the MARS-revised (Plake & Parker, 1982) and the Abbreviated Math Anxiety Scale (Hopko et al., 2003); thus, the number of items may not fully explain the differences. It could also be that another one of the moderators we tested, specifically the components of math anxiety, plays a role in the differences found in the relations between math achievement and these scales (results discussed in next section). However, none of the math anxiety scales that were stronger (i.e., PISA, AEQ, FSMAS, MAS [Betz]) or weaker (i.e., MARS-based, one item) were consistently in any of the categories that we coded for in the components of math anxiety variable. Thus, the reason for the differences found here still remains an unanswered question. Overall, future research is needed to investigate these and other potential reasons why differences exist in the relations between math achievement and scores on these adolescent and adult math anxiety scales.

We also found that math anxiety scales assessing anxiety in the broader subject of math were significantly more related to math achievement than scales assessing anxiety in statistics. This finding suggests that the relation between math anxiety and math achievement is different depending on the math content of the anxiety scale. However, we also found that math anxiety topic is a significant moderator only in the case of assessments testing non-statistics math content (i.e., more related to math anxiety scales that to statistics anxiety scales). Statistics anxiety and math anxiety were similarly related to math achievement when the assessment was testing statistics content. These findings indicate that the content of the math assessment is also an important moderator of this relation, with the content of statistics playing a role in whether we find differences in the relation between math achievement and broader math anxiety scales compared to the relation between math achievement and statistics-specific anxiety scales.

Components of math anxiety. With regard to the moderator of components of math anxiety, one might have expected that the strongest correlation would be between math evaluation anxiety and math achievement, because math achievement was primarily represented by math tests in this meta-analysis and the component of math evaluation anxiety specifically targets the situation of a math test. However, we found stronger relations between math achievement and the cognitive worry component of math anxiety compared to those effect sizes measuring math anxiety through the single component of math evaluation and through both components of math evaluation and learning anxiety. The relation with math achievement was also stronger with math anxiety measured as math learning anxiety and emotionality, separately, than those relations measured with both components of math evaluation and learning anxiety. This suggests that the negative relation between math anxiety and math achievement is stronger, at least when compared to items that ask about testing or testing and both learning situations in math, when the anxiety items ask about negative expectations and self-deprecating thoughts related to math stimuli or situations or when they ask about the process of learning in math as well as when they ask about physiological reactions during math situations. The stronger correlations found with the worry component of anxiety provide some evidence for the attentional control theory. This theory hypothesizes that, in a math context, anxious thoughts and worry take up limited cognitive resources that are needed to complete a math-related task, which subsequently reduces both efficiency and accuracy on the task (Eysenck et al., 2007).

Math assessments. Regarding math achievement measures, a previous meta-analysis found weaker relations between math anxiety and commercially-developed and psychometrically-validated assessments than between math anxiety and researcher-made achievement measures and math teachers' grades (Ma, 1999). This finding is unexpected when considering other work that shows that greater levels of anxiety are more often associated with high-stakes testing (Cassady & Johnson, 2002), which would fit into the psychometrically-validated test group from Ma's (1999) meta-analysis. In the present meta-analysis, we were able to expand on the types of math assessments to include high-stakes standardized testing situations, standardized tests used for research, non-standardized research tests, math course grades, and math exam grades.

Similar to the previous meta-analysis, we found significant relations between math anxiety and each of these types of math assessments; however, the moderator effect we found was different from that found in Ma's 1999 meta-analysis. We were able to separate what the 1999 meta-analysis considered to be an "other" category into three categories of non-standardized researcher-made math assessments, exam grades, and math course grades (or math GPA). We found that the relation was weaker between math anxiety and math exam grades compared to the relations between math anxiety and standardized measures for research and between math anxiety and non-standard researcher made measures. In other words, the relation between math achievement and math anxiety was significantly stronger, and more negative, when the achievement measure consisted of standardized tests used for research and non-standardized research-made compared to when the math assessment consisted of a math test or exam that were not high-stakes and mostly math class-level exams. Our lack of significant findings with regard to the high-stakes math tests subgroup also opposes the notion that, specifically with math-related tests, high-stakes exams are more related with math anxiety than other forms of math assessments. We find that the relation between math anxiety and high-stakes exams is similar to the relation between math anxiety and other types of math tests.

These findings have implications for education practitioners, parents, and researchers alike. For educators, knowing that the relation between math achievement and math anxiety is consistently weaker when the math assessment consists of a math exam that is often encountered in a regular classroom setting may be useful when preparing curriculum and using class math tests as sources of math knowledge that are less related with the math anxiety that a student may have. For parents, the weaker relation can also provide some relief for the various types of math assessments their children encounter throughout the school year. For researchers investigating the math anxiety-math achievement association in lab studies and experiments, this finding suggests that results from lab experiments and research projects are more likely to find stronger relations with math anxiety than when using math exam grades as measures of math achievement. Thus, it may be beneficial for researchers to know ahead of time that the relation between math anxiety and math achievement may be different depending on the measure of achievement they decide to use, whether it be already available exam grades provided by teachers or whether they decide to collect their own math achievement data.

Math content. In the final moderation analysis based on measure characteristics, we tested whether the math content area of the math achievement measure was a moderator of the relation between math anxiety and math achievement. Hembree (1990) had previously reported significant relations, but did not test for differences in the relations between math anxiety and a variety of math content areas, such as computation, math concepts, problem solving, abstract reasoning, and spatial ability, for students in grade 7, high school, and postsecondary school. In the present analysis, we tested the relations between math anxiety and math achievement for assessments testing knowledge in a single content area for samples representing a wider grade level range than previously tested (i.e., grade 1 students through non-student adults). Our results indicated that there are significant negative correlations between math anxiety and most types of single-content math assessments, with the exception of the content area of approximate number system (ANS: r = -.09; other areas: rs ranged from -.20 to -.38).

We did not find evidence that math content area moderated the relation with math anxiety. Our supplemental analyses did suggest that there are grade-level differences for certain math content areas, but this is not the case when taking all grade levels into account. Some theories, such as the attentional control theory described earlier in this paper, have suggested that math anxiety disrupts cognitive resources such as working memory during achievement tasks (Eysenck, Derakshan, Santos, & Calco, 2007). Some previous research also indicates that math anxiety has negative consequences with complex math that requires greater use of cognitive resources (Ashcraft, 2002); however, our current findings suggest that the relation is similar across math content areas, whether they measure achievement in more basic math knowledge or more advanced content.

Publication Bias

Publication bias was assessed in the present meta-analysis in order to examine whether there is a tendency to publish stronger effect sizes compared to weaker ones and whether the available effect sizes included in our meta-analytic samples are representative of the true effect size or skewed due to missing studies (i.e., the “file drawer problem”; Rosenthal, 1979). Previous work has found that published studies reported weaker correlation between math anxiety and math achievement than did unpublished studies, which suggests an unexpected "positive publication bias" (Ma, 1999). In the current meta-analysis, we found the opposite to be the case, where effect sizes published in peer-reviewed journals were significantly stronger than the effect sizes reported in unpublished and grey literature. This finding supports the typical pattern of "negative" publication bias, in which smaller effect sizes and non-significant findings tend to not be published.

Additionally, our funnel plot and Egger test results indicate the presence of a skew against large effect sizes for all sample sizes in the distribution of the included effect sizes within the meta-analytic sample. The trim-and-fill method results further suggest that there are effect sizes missing and that inclusion of those effect sizes would produce a statistically significant, moderate, and negative adjusted overall effect size, similar to the original effect size reported here. Based on all of our publication indices, although the file drawer problem is an issue, our average weighted effect size is not significantly impacted by the potentially missing studies. Moreover, previous work has suggested that the trim-and-fill method should be used as a sensitivity analysis instead of an index of publication bias (Peters et al., 2007). It is unknown whether publication bias is the only cause of funnel plot asymmetry; often meta-analyses with large between-study heterogeneity in their effect sizes are due to tested or untested moderators. In these cases, use of the trim-and-fill method underestimates the true effect size when there is no publication bias. Overall, the publication bias evidenced by our indices is likely not a critical issue that would negatively impact the interpretation or significance of our main meta-analytic results.

Connections with Recent Work

One important note to mention is that, simultaneous to us working on this meta-analysis, two other research groups worked on and subsequently published meta-analyses of the relation between math anxiety and math performance (Namkung, Peng, & Lin, 2019; Zhang, Zhao, & Kong, 2019). There are some key differences in the search strategies, inclusion and exclusion criteria, and effect size extraction techniques between these two recently published meta-analyses and the present one that should be mentioned. In general, our study was more thorough and inclusive, as we chose to include adult samples, include unpublished data, and conduct author queries for missing information. This led us to have many more effect sizes (k = 747) compared to Zhang et al. (k = 84) and Namkung et al. (k = 478). Despite these differences, the main findings were generally similar across studies, suggesting that we are homing in on the magnitude of the relation between math anxiety and achievement. Our overall correlation was -.28 compared to a correlation of -.32 in Zhang et al. and -.34 in Namkung et al. An investigation of the articles included across the meta-analyses shows a lot of overlap, suggesting that we did not miss research included in these other studies. Therefore, our study makes an important unique contribution to this literature, while also being generally consistent with the findings of these other research groups.

Limitations

Although meta-analyses provide an opportunity to aggregate a large number of effect sizes from many studies that assess relevant factors, which then increases the power to draw more accurate, statistically-driven conclusions about the relations, the current set of analyses is not exhaustive in explaining the relation between math anxiety and math achievement. One limitation of a meta-analysis that considers only the zero-order correlation is that other relevant factors that may account for the relation, such as test anxiety (Devine et al., 2012) or math confidence (Hembree, 1990), are not examined in conjunction with the variables of interest. Thus, there may be confounding variables we do not account for that are influencing the relations we found between math anxiety and math achievement.

Another limitation is that any unexplained variance that remains in the accumulated effect sizes after accounting for all moderators tested suggests that there are other study factors, not included in the meta-analysis, that may also moderate the relation tested. For example, environmental factors, such as math activities done in the home (del Rio, Susperreguy, Strasser, & Salinas, 2017), have been previously highlighted as potentially important moderators of the relation between math anxiety and math achievement. Although many of the reasons posited to explain the significant moderators require direct testing through studies beyond a meta-analysis, additional work is needed to better explain the factors that influence the strength of the relation between math anxiety and math achievement.

Additionally, this study is limited to the relation between the emotion of anxiety in math and achievement. However, the study of the relations between different emotions and math achievement and how it differs from the relation between math anxiety and math achievement may also be an important gap to fill for future meta-analytic work.

Meta-analyses are dependent on the quality of the studies that are included in them, particularly because they rely on effect size parameters from studies that vary in the rigor of their study designs (Gersten, Baker, & Lloyd, 2000). Thus, another limitation of this meta-analysis is that the quality of the included studies was not examined as a moderator. There are instruments that have been previously developed to measure quality of reviews (Oxman & Guyatt, 1991), which have been used as templates for researchers to assess study quality in a meta-analysis

(Downs & Black, 1998). Future meta-analyses on this topic should consider study quality as an important potential moderator.

There were also some limitations related to our search strategy and timeline. The search was done for articles available or published between January of 1992 through May of 2018. Thus, we may be missing studies that have been published since our last search that may impact the findings reported in our meta-analysis. Importantly though, we did solicit effect sizes from unpublished and ongoing studies from researchers in the area and were able to include 26 additional effect sizes from unpublished data that may have been published in the interim between our last search and our writing up of the results. Second, the search terms and databases used may not be expansive or broad enough to capture all available and relevant articles. Specifically, relevant studies, may have been missing due to the narrowness of the search terms used (i.e., math anxiety versus anxiety). While the results may still be generalizable, it is important to consider that there are likely some missing effect sizes that may be relevant for understanding the relation between math anxiety and math achievement.

An additional issue with our search strategy is the omission of the OECD 2013 report containing PISA 2012 data (OECD, 2013). PISA is a large international effort to gauge achievement levels every four years from over 510,000 high school students from 65 countries (OECD, 2013). The PISA 2012 data were published in a 2013 report, but this report was not found in the three journal databases we searched and therefore we did not include it in our sample. However, we did include effect sizes from previous PISA years and a few country's effect sizes from PISA 2012 when empirical studies contained these effect sizes (i.e., Lee, 2013; Thien & Ong, 2015). The PISA 2012 sample consists of 15-year old students, and their average correlation across countries was -.34, which is the same magnitude of the correlation for high school students in the present study. This suggests the findings from our meta-analysis would likely not change with the inclusion of all PISA 2012 results.

Another limitation of the current meta-analysis is related to the low response rate by contacted authors for correlation information from potentially included studies. We sent first- or corresponding-authors email requests for correlation coefficient information for almost 200 studies, but the response rate was only 35%. The date criteria we chose extended as far back as 1992, and many researchers had likely moved from their original institutions or changed their originally listed email addresses by the time they were contacted. We opted to email authors rather than contact them through other modes of communication, which may have impacted the response rate. Although the response rate was low, the trim-and-fill analysis indicated that even if we were to uncover the file drawer problem and add 130 missing studies to fill in the unrepresented areas of our funnel plot, this addition would not have impacted the magnitude of the average correlation we found in our meta-analysis.

Additionally, the inter-rater reliabilities for two variables had lower-than-desired values (<80%; sample size: 72%; number of effect sizes: 75%). One reason for the low inter-rater reliability was because of the challenge of accurately coding information from experimental studies, specifically for control and experimental groups, separately. Some other reasons include one coder not finding the sample size in the paper and listing it as needing an author query, one coder reporting the full sample and the other coder reporting the analytic sample for that effect size, and true coding errors. Importantly though, a large number of the codes from experimental studies required an author query and thus the number of effect sizes and sample size variables were subsequently checked by the first author, which may help to increase the overall inter-rater reliability for these variables.

Finally, many of the effect sizes in our meta-analytic sample come from small convenience samples. Additionally, many of the samples are from Western countries (N = 626/744; 84%) and college students (N = 355/750; 47%). This minimal diversity and lack of representativeness are a limitation of our meta-analytic results, specifically for the race and ethnicity and continent moderator analyses we were able to conduct and present in this paper. Research on the relation between math anxiety and math achievement needs to continue to seek out more diverse and more representative samples to fully understand whether there are truly varying associations between math anxiety and math achievement for certain moderators.

Implications

In the ever-evolving sectors of education, researchers, teachers, and education policy-makers must constantly stay updated on the factors related to math achievement. Moreover, the implications of this relation during childhood and adolescence on future career and educational pathways is significant for both individuals' career successes and society's needs of a larger STEM workforce (Wigfield & Eccles, 2000; Wang & Degol, 2013). Math anxiety has been previously implicated as an important factor related to math achievement (Hembree, 1990; Ma, 1999). The present meta-analysis provides further support for the importance of the co-occurrence of math anxiety and math achievement. This relation is critical for people of all ages, a diverse set of demographics, and for different scale and assessment characteristics.

These current findings inform the development and implementation of interventions that aim to reduce math anxiety and/or increase math achievement. Previous experimental work has investigated the effectiveness of strategies such as writing sessions prior to a math task (Park, Ramirez, & Beilock, 2014) or reappraisal of anxiety (Jamieson, Mendes, Blackstock, & Schmader, 2010) to reduce math anxiety. Other work has focused on reducing the math achievement-math anxiety link by targeting math problem solving through cognitive tutoring (Supekar, Iuculano, Chen, & Menon, 2015). Importantly, the present work indicates that the association is detectable in children as young as students in grade 1. Thus, interventions such as those just described may be prudent for students as young as those in early elementary and could target math anxiety or achievement in content areas as foundational as basic number knowledge and whole number calculations.

Conclusions

The present meta-analysis provides an updated summary of the association between math anxiety and math achievement and moderators of the relation. We found that a small-to-moderate negative association is evident and robust for students as young as grades 1 and 2 all the way to up to non-student adults. These significant, small-to-moderate relations are evident across all types of math content areas, with the exception of content measuring the approximate number system. The strength of the relation with math achievement differs depending on the math anxiety scale used and the math topic that the anxiety scale asks about, a finding that can inform the choice of math anxiety scales for future research. Finally, the relation between math anxiety and math achievement is stronger for samples that are not selected for low math ability compared to samples that are selected for low math ability, providing some evidence against current research suggesting that samples selected for low math ability tend to have stronger relations between their achievement in math and of math anxiety. Overall, this work has both theoretical implications for current theories explaining the math anxiety math achievement and practical implications that will advise the future development of effective interventions to lower math anxiety, reduce its relation with math achievement, and improve math achievement in the long run.

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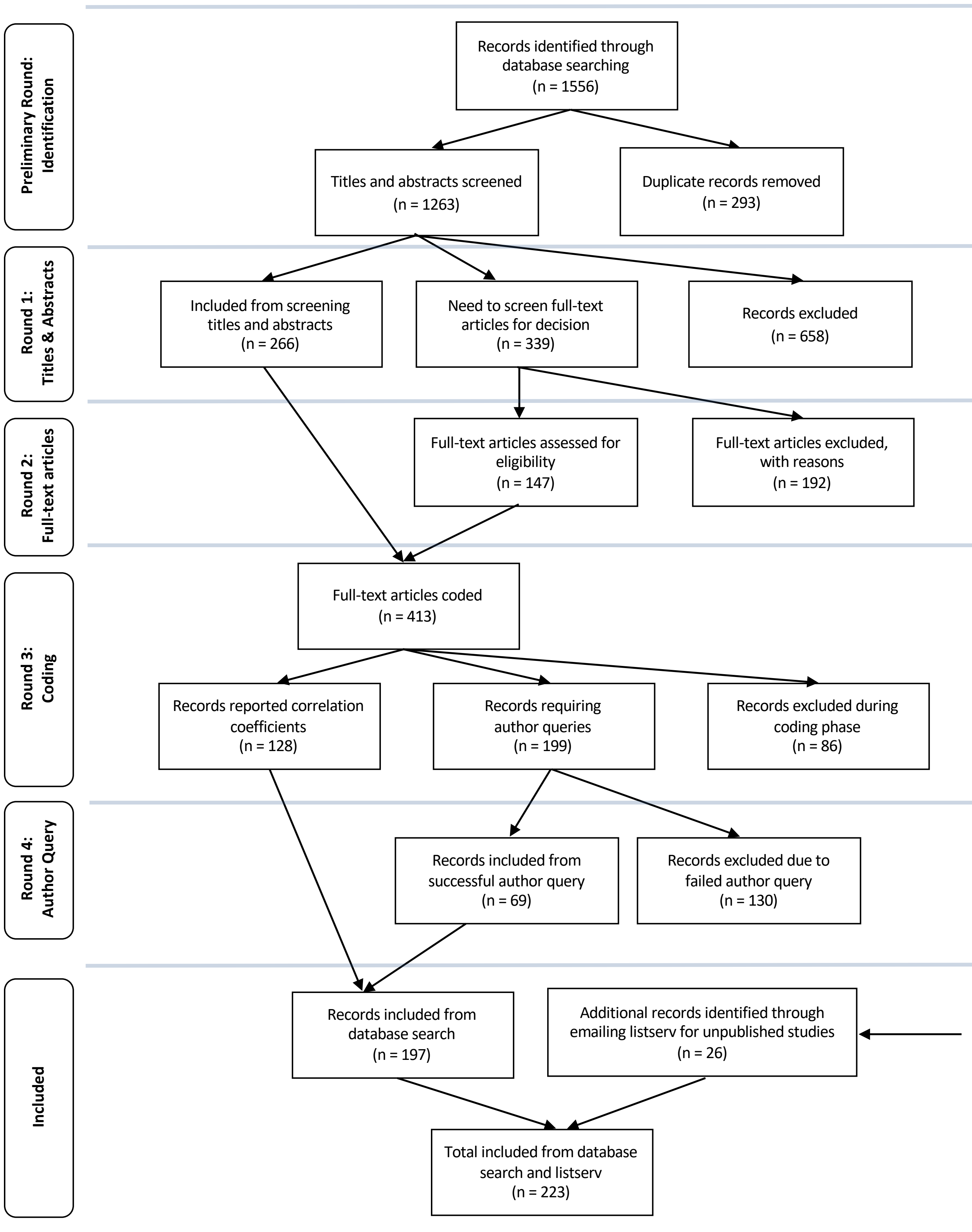

Figure 1. Flow Diagram of the Excluded and Included Studies.

Table 1
Math Assessment and Math Anxiety Scale Categories, Definitions, and Examples

Category	Definition	Example measures/items
Type of Math Anxiety Scale		
Child Math Anxiety	Developed for the intended use of measuring math anxiety in children	Scale for Early Math Anxiety
Adolescent and Adult Math Anxiety	Developed with the intended or primary use of measuring math anxiety in adolescents or adults or with no intention of measuring a specific age group/grade level during childhood	Math Anxiety Rating Scale
Math Anxiety	Items in a measure developed for the intended use of measuring anxiety in a broad math context	Math Anxiety Rating Scale
Statistics Anxiety	Items in a measure developed for the intended use of measuring anxiety in a statistics context	Statistics Anxiety Scale
Components of Math Anxiety		
Worry	Cognitive dimension of anxiety; negative expectations and self-deprecating thoughts about a math situation*	--
Emotionality	Physiological dimension of anxiety; feelings of dread, nervousness, and unpleasant physiological reactions to math situations*	--
Math Evaluation Anxiety	Anxiety felt while taking a math test or while doing math in front of others	--
Math Learning Anxiety	Anxiety felt in the classroom or while engaging in a math task	--
Type of Math Assessment		
Standardized high-stakes	Measures used for selection into institutions or receipt of license or degree	SAT, ACT
Standardized measures for research	Measures with a standard protocol, often validated to measure achievement, may have manual	Woodcock-Johnson Applied Problems
Non-standardized or research-made	Measures with no standard protocol or created by the researcher without validation	Subtraction problems created by researcher
Course grade	Grade assigned for a particular math course	Developmental Algebra course grade
Exam/test grade	Grade from course exam on specific math material	Statistics mid-term exam
Content of Math Assessment		
Approximate Number System	Tasks that measure intuitive number and magnitude system with non-symbolic representations	The Dots Task
Basic Number Knowledge	Knowledge about numerosity, relations of numbers, counting words, and symbolic numbers**	Number line task
Whole Number Calculation	Single or multi-digit addition, subtraction, multiplication, and division**	Woodcock-Johnson Math Fluency
Word Problem Solving	Tasks with a problem narrative where relevant information needs to be isolated, number sentences constructed, and missing numbers solved for in order to find the answer	WIAT Math Reasoning Subtest
Fractions, Decimals, & Percentages	Knowledge of part-whole relation and interpreting measurement of fractions**	Knowledge of Fractions Assessment
Geometry	Tasks asking about shape, size, position of figures relative to others, and properties of space**	KeyMath3 Geometry Subtest
Algebra	Knowledge and application of pre-learned symbol manipulation arguments**	KeyMath3 Algebra Subtest
Statistics, Data Analysis, & Probability	Knowledge in analysis and interpretation of data	Statistics Concept Inventory

Note. *definition adapted from Liebert & Morris, 1967; **definition adapted from Peng, Namkung, Barnes, & Sun, 2015.

Table 2

Multi-level Model Results for Overall and Moderator Analyses

Moderator	*F(df1, df2)*	Between-study variance (Level-1)	Within-study variance (Level-2)	*QE(df)*	I^2
Overall	--	.01	.02	7797.56(749)**	90.39%
Gender	1.19(1, 88)	.02	.01	494.51(88)**	82.00%
Race	0.28(1, 174)	.003	.01	609.50(174)**	71.29%
Continent	1.56(5, 735)	.01	.02	7354.65(735)**	89.94%
Grade level	6.64(5, 741)**	.01	.02	6582.82(741)**	88.67%
Teachers	0.59(1, 745)	.01	.02	7755.88(745)**	90.38%
Low math ability	6.29(1, 745)*	.01	.02	7732.83(745)**	90.35%
Child math anxiety scale	1.26(5, 149)	.01	.02	735.33(149)**	79.06%
Adolescent/Adult math anxiety scale	6.87(9, 502)**	.004	.02	5233.87(502)**	90.24%
Anxiety scale by topic	12.14(1, 745)**	.01	.02	7199.63(745)**	89.64%
Components of math anxiety	3.02(5, 236)*	.01	.01	1273.77(236)**	81.08%
Math assessment	2.34(4, 742)*	.01	.02	7398.40(742)**	89.92%
Math content area	1.40(7, 327)	.01	.02	1176.00(327)**	71.60%

Note. **p* < .05; ***p* < .001; *F* = omnibus test; *df* = degrees of freedom; *QE* = Residual Heterogeneity; I^2 = Heterogeneity Percentage.

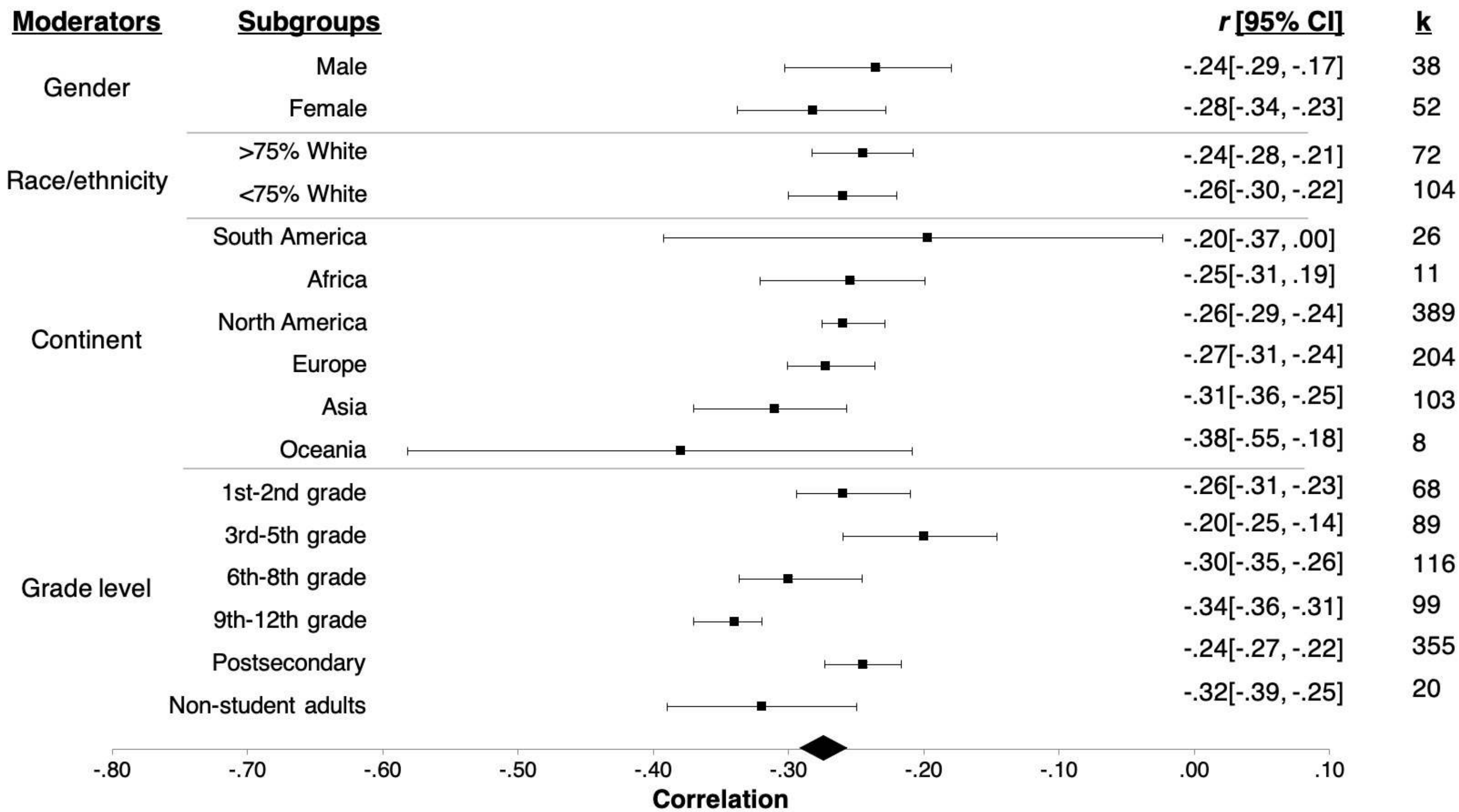

Figure 2. Average Effect Sizes for Demographic Moderators.

Table 3

Univariate Pairwise Comparisons of Grade Level and Low Math Ability Moderator

		95% CI		
Demographic	beta	LL	UL	k
Grade level				
1-2 vs. 3-5	.08*†	.02	.15	157
1-2 vs. 6-8	-.04	-.11	.04	184
1-2 vs. 9-12	-.07*	-.14	-.01	167
1-2 vs. PS	.03	-.05	.10	423
1-2 vs. Non-student adults	-.05	-.14	.03	88
3-5 vs. 6-8	-.11**	-.19	-.04	205
3-5 vs. 9-12	-.14***	-.21	-.08	188
3-5 vs. PS	-.05	-.11	.02	444
3-5 vs. Non-student adults	-.14*	-.25	-.02	109
6-8 vs. 9-12	-.03	-.09	.02	215
6-8 vs. PS	.07**	.02	.12	471
6-8 vs. Non-student adults	-.02	-.13	.08	136
9-12 vs. PS	.10***	.05	.14	454
9-12 vs. Adult	.01	-.08	.10	119
PS vs. Non-student adults	-.09	-.19	.01	375
Low math ability				
Low math ability vs. non-low math ability	-.21**	-.37	-.04	747

Note. *p < .05; **p < .01; ***p < .001; †predictor variables no longer significant after Benjamini-Hochberg correction; k = number of effect sizes;
PS = Postsecondary.

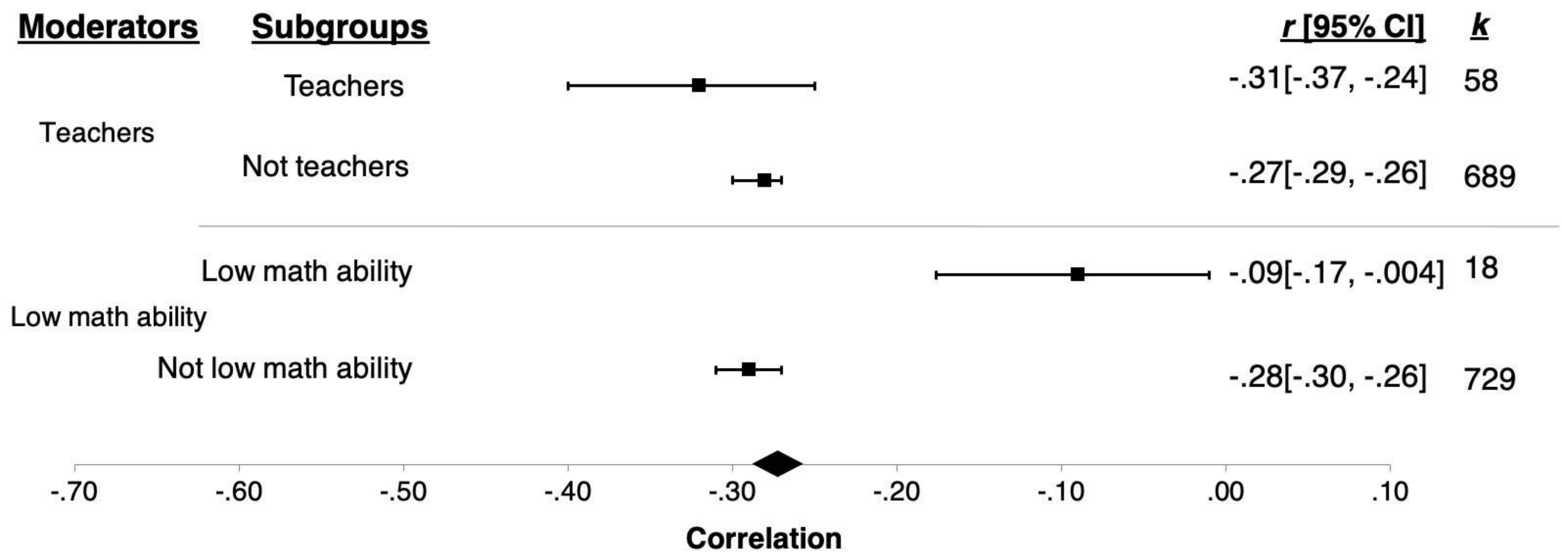

Figure 3. Average Effect Sizes for Teacher and Low Math Ability Moderators.

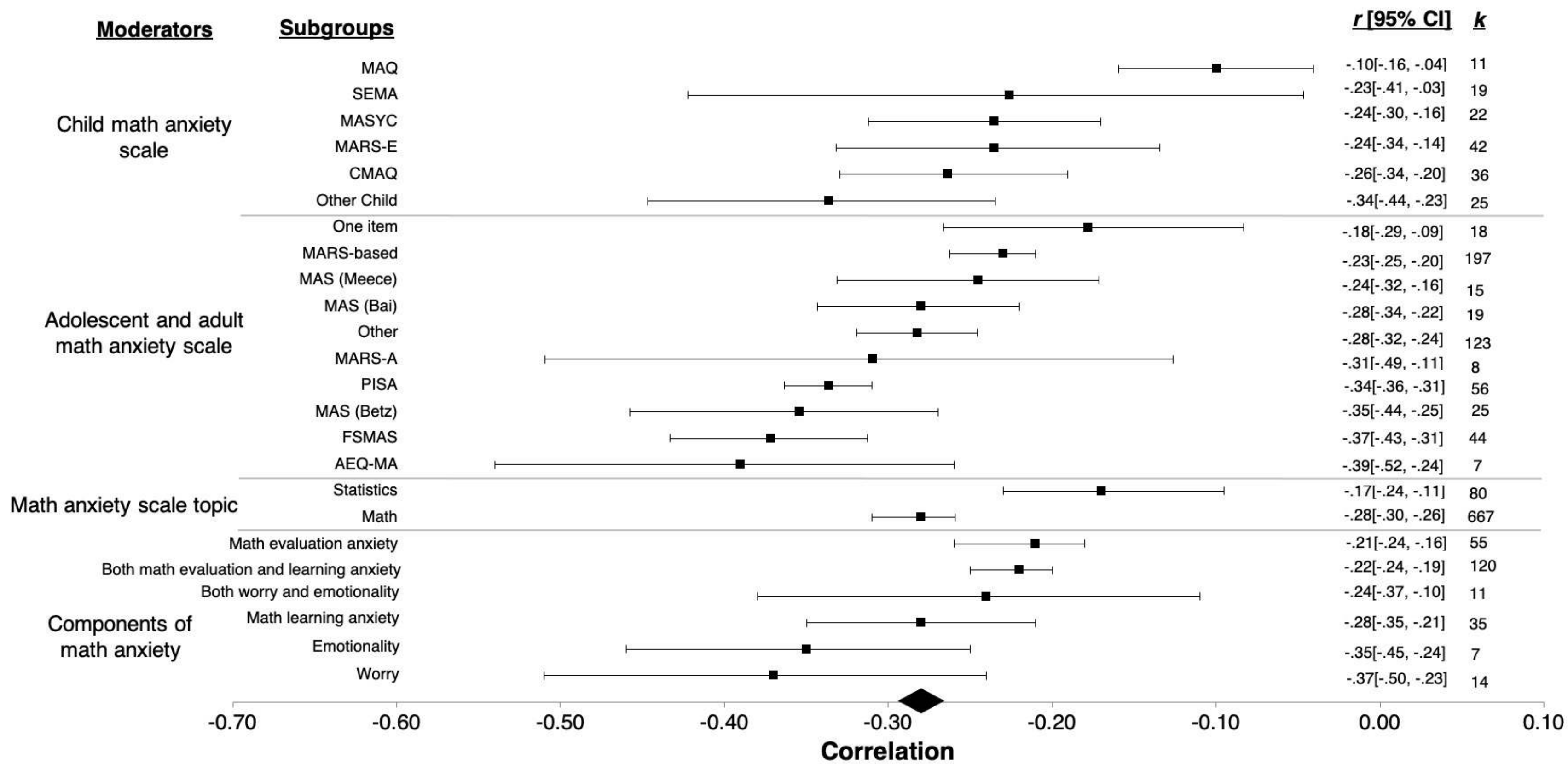

Figure 4. Average Effect Sizes for Math Anxiety Scale and Components of Math Anxiety Moderators.

Table 4

Univariate Pairwise Comparisons of Adolescent/Adult and Math Topic Math Anxiety Measure Moderators

		95% CI		
Measure	beta	LL	UL	k
Adolescent/Adult Math Anxiety Measure				
MARS vs. One item	0.03	-0.05	0.10	215
MARS vs. FSMAS	-0.16***	-0.23	-0.09	241
MARS vs. MARS-A	-0.11	-0.23	0.02	205
MARS vs. PISA	-0.12***	-0.16	-0.08	253
MARS vs. AEQ	-0.18**	-0.29	-0.06	204
MARS vs. MAS (Betz)	-0.14***	-0.22	-0.05	222
MARS vs. MAS (Meece)	-0.02	-0.13	0.09	212
MARS vs. MAS (Bai)	-0.05	-0.15	0.06	216
MARS vs. Other	-0.05	-0.10	0.002	320
One item vs. FSMAS	-0.21***	-0.33	-0.09	62
One item vs. MARS-A	-0.14	-0.34	0.06	26
One item vs. PISA	-0.16***	-0.24	-0.08	74
One item vs. AEQ	-0.39***	-0.50	-0.27	25
One item vs. MAS (Betz)	-0.18**†	-0.32	-0.04	43
One item vs. MAS (Meece)	-0.06	-0.19	0.07	33
One item vs. MAS (Bai)	-0.10	-0.22	0.03	37
One item vs. Other	-0.06	-0.15	0.02	141
FSMAS vs. MARS-A	0.05	-0.12	0.23	52
FSMAS vs. PISA	0.05	-0.01	0.11	100
FSMAS vs. AEQ	-0.02	-0.17	0.13	51
FSMAS vs. MAS (Betz)	0.02	-0.10	0.14	69
FSMAS vs. MAS (Meece)	0.14*†	0.01	0.28	59
FSMAS vs. MAS (Bai)	0.12	-0.01	0.24	63
FSMAS vs. Other	0.10**†	0.02	0.18	167
MARS-A vs. PISA	0.0003	-0.11	0.11	64
MARS-A vs. AEQ	-0.08	-0.35	0.18	15
MARS-A vs. MAS (Betz)	-0.03	-0.25	0.18	33
MARS-A vs. MAS (Meece)	0.07	-0.16	0.31	23
MARS-A vs. MAS (Bai)	0.06	-0.16	0.27	27
MARS-A vs. Other	0.05	-0.09	0.19	131
PISA vs. AEQ	-0.06	-0.15	0.04	63
PISA vs. MAS (Betz)	-0.02	-0.10	0.06	81
PISA vs. MAS (Meece)	0.10*†	0.02	0.19	71
PISA vs. MAS (Bai)	0.07	-0.01	0.15	75
PISA vs. Other	0.06*†	0.01	0.11	179
AEQ vs. MAS (Betz)	0.05	-0.14	0.23	32
AEQ vs. MAS (Meece)	0.16	-0.03	0.35	22
AEQ vs. MAS (Bai)	0.13	-0.04	0.30	26
AEQ vs. Other	0.12	-0.01	0.25	130
MAS (Betz) vs. MAS (Meece)	0.11	-0.05	0.28	40
MAS (Betz) vs. MAS (Bai)	0.09	-0.06	0.24	44
MAS (Betz) vs. Other	0.08	-0.02	0.18	148
MAS (Meece) vs. MAS (Bai)	-0.03	-0.13	0.07	34
MAS (Meece) vs. Other	-0.04	-0.16	0.08	138
MAS (Bai) vs. Other	-0.01	-0.12	0.10	142
Anxiety Topic				
Math vs. Statistics	.09***	.04	.14	747

Note. **p* < .05; ***p* < .01; ****p* < .001; †predictor variables no longer significant after Benjamini-Hochberg correction; CI = Confidence Interval; LL = Lower Level; UL = Upper Level; k = number of effect sizes; MARS = Math Anxiety Rating Scale; FSMAS = Fennema Sherman Math Anxiety Scale; MARS-A = Math Anxiety Rating Scale – Adolescents; PISA = Programme for International Student Assessments; AEQ = Achievement Emotion Questionnaire; MAS = Math Anxiety Scale.

Table 5

Univariate Pairwise Comparisons of Math Anxiety Component Subgroups

Subscale	beta	95% CI LL	95% CI UL	k
Worry vs. Emotionality	.04	-.08	.16	21
Worry vs. Both Worry and Emotionality	.13	-.11	.37	25
Worry vs. Math Evaluation Anxiety	.18**	.07	.30	69
Worry vs. Math Learning Anxiety	.10	-.05	.26	49
Worry vs. Both Math Evaluation and Learning Anxiety	.17***	.07	.27	134
Emotionality vs. Both Worry and Emotionality	.12	-.07	.32	18
Emotionality vs. Math Evaluation Anxiety	.14*†	.02	.26	62
Emotionality vs. Math Learning Anxiety	.08	-.08	.25	42
Emotionality vs. Both Math Evaluation and Learning Anxiety	.15**	.05	.25	127
Both Worry and Emotionality vs. Math Evaluation Anxiety	.03	-.10	.15	66
Both Worry and Emotionality vs. Math Learning Anxiety	-.03	-.22	.15	46
Both Worry and Emotionality vs. Both Math Evaluation and Learning Anxiety	.02	-.10	.13	131
Math Testing Anxiety vs. Math Learning Anxiety	-.04	-.09	.02	90
Math Testing Anxiety vs. Both Math Evaluation and Learning Anxiety	-.002	-.05	.05	175
Math Learning Anxiety vs. Both Math Evaluation and Learning Anxiety	.08**	.02	.14	155

Note. $p < .05$*; $p < .01$**; $p < .001$***; †predictor variables no longer significant after Benjamini-Hochberg correction; CI = Confidence Interval; LL = Lower Level; UL = Upper Level; k = number of effect sizes.

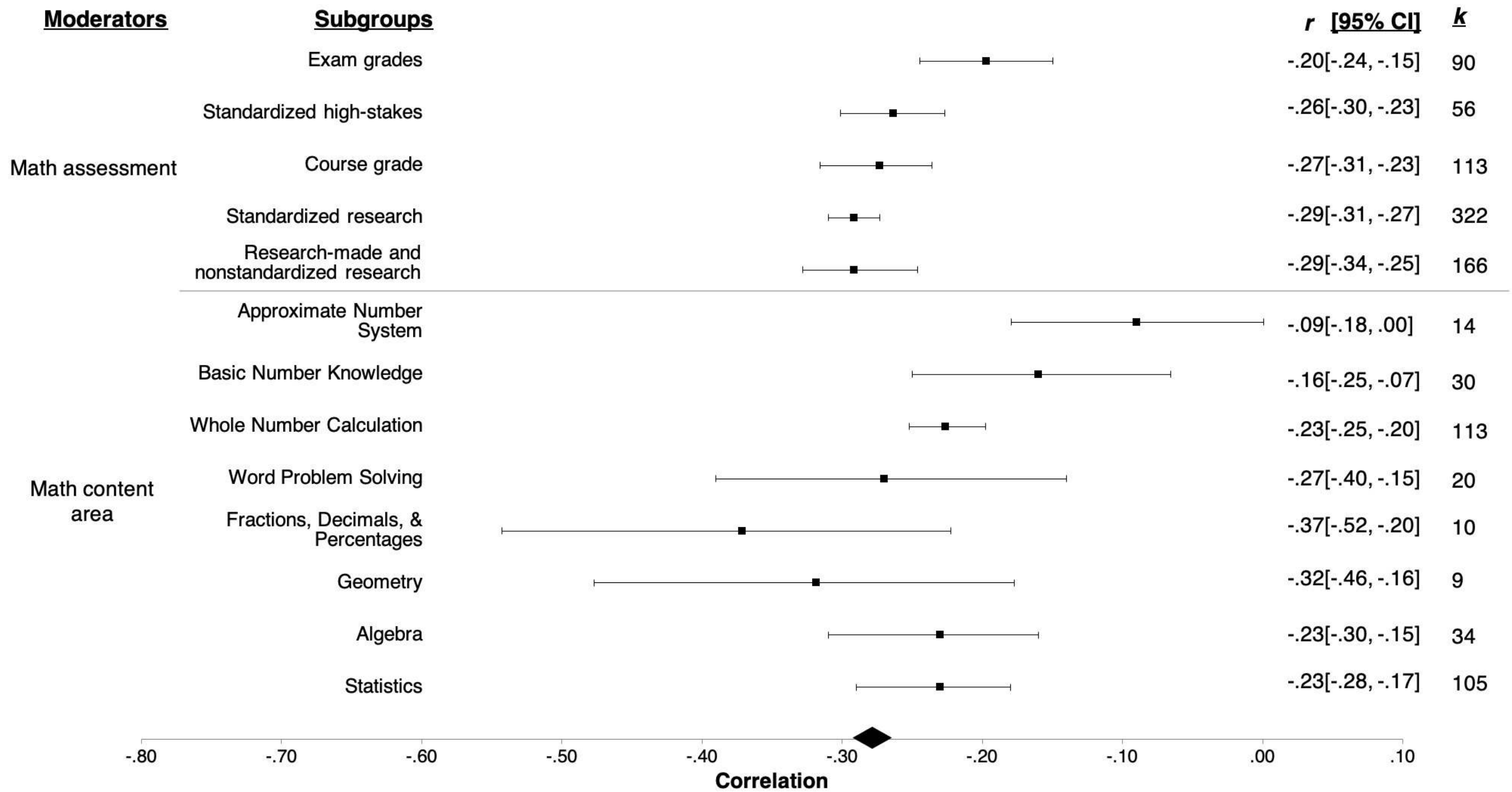

Figure 5. Average Effect Sizes for Math Assessment and Math Content Area Moderators.

Table 6

Univariate Pairwise Comparisons of Math Assessment Subgroups

Subscale	beta	95% CI LL	95% CI UL	k
High stakes tests vs. Standardized research assessments	-.005	-.06	.05	378
High stakes tests vs. Nonstandardized research assessments and Other tests	-.05	-.12	.01	222
High stakes tests vs. Course grade	-.02	-.08	.04	169
High stakes tests vs. Exam grade	.06	-.002	.13	146
Standardized research assessments vs. Nonstandardized research assessments and Other tests	.01	-.03	.05	488
Standardized research assessments vs. Course grade	.01	-.03	.05	435
Standardized research assessments vs. Exam grade	.08**	.03	.14	412
Nonstandardized research assessments and Other tests vs. Course grade	.02	-.05	.08	279
Nonstandardized research assessments and Other tests vs. Exam grade	.09*	.02	.15	256
Course grade vs. Exam grade	.06*†	.003	.11	203

Note. $p < .05$*; $p < .01$**; †predictor variables no longer significant after Benjamini-Hochberg correction; CI = Confidence Interval; LL = Lower Level; UL = Upper Level; k = number of effect sizes.

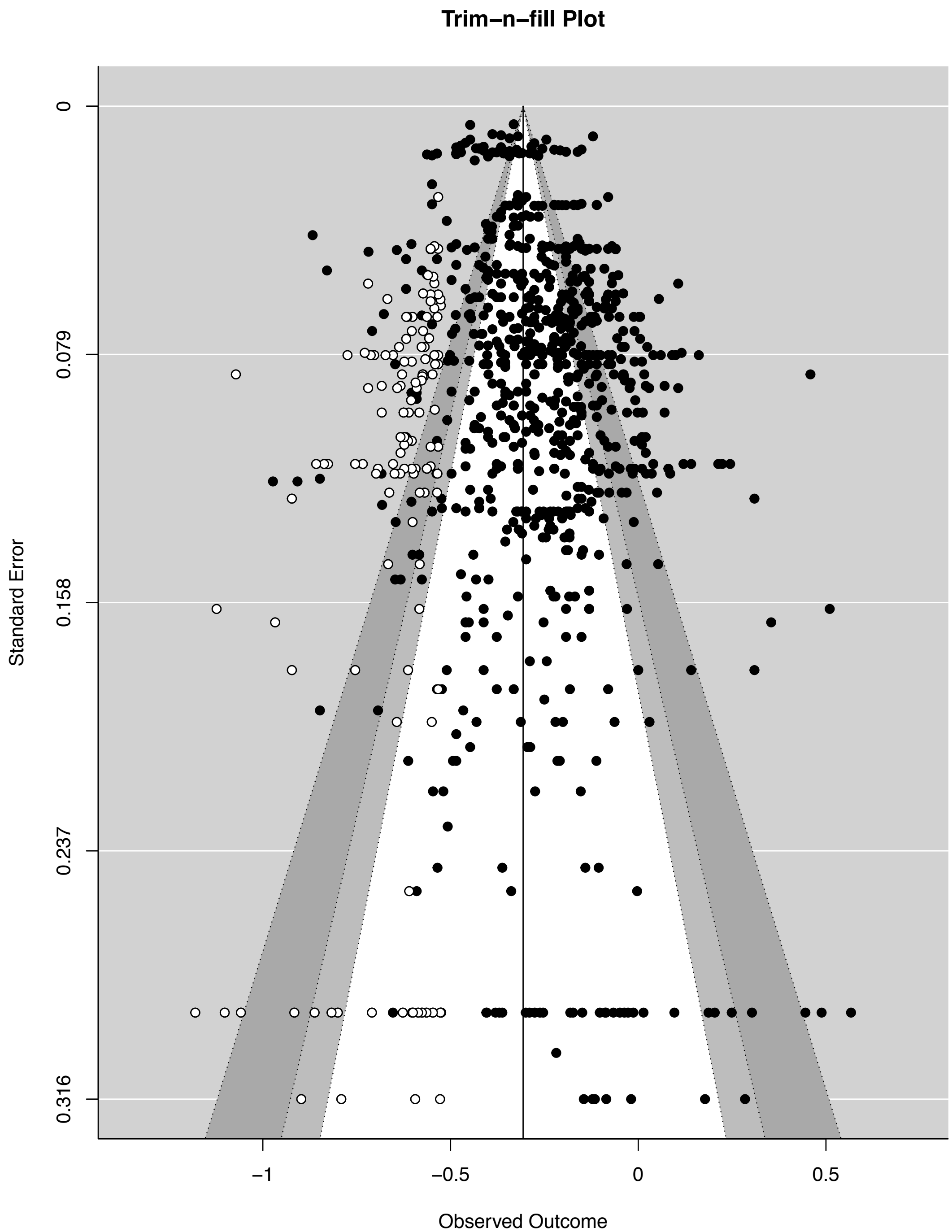

Figure 6. Funnel plot of Fisher's Z-transformed correlations for all included effect sizes (black dots) and trim-and-fill analysis (white dots).