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Anxious for Answers: A Meta-Analysis of the Effects of Anxiety on African American K-12 Students' Mathematics Achievement

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ABSTRACT Mathematics anxiety is recognized as a significant performance impediment that affects students across multiple ethnic and economic backgrounds. However, research has yet to fully examine the possible differential effect of mathematics anxiety on underrepresented K-12 students. Specifically, given the long-standing achievement gap between African American and White students it is imperative that the possible differential effect of mathematics anxiety on African American students be addressed. The purpose of this study was to utilize the techniques of meta-analysis to summarize the effects of anxiety on mathematics achievement in K-12 African American student populations. The results suggest that anxiety has a statistically significant effect on the mathematics achievement of representative samples of African American students. Furthermore, this effect is mediated by student grade level. More representative research is needed to better ascertain the factors that promote and sustain mathematics anxiety in African American student populations. In particular, studies that disaggregate results based on student race are necessary for more robust estimates of this phenomenon.

KEYWORDS *achievement gap, African American students, mathematics anxiety*

Mathematics anxiety is recognized as a significant performance impediment that affects students across multiple ethnic and economic backgrounds. Behavioral research has shown that math anxiety has a negative effect on the performance of basic numerical operations, including counting, addition, and subtraction with samples of competent adults (Maloney, Risko, Ansari, & Fugelsang, 2010). Despite the detrimental effects of mathematics anxiety on basic mathematics performance, these effects tend to reach far beyond the realm of academic performance. Thus, the definition of mathematics anxiety has evolved over the years and is now more appropriately defined as a negative emotional response characterized by avoidance as well as feelings of stress and anxiety in situations involving mathematical reasoning (Ashcraft & Ridley, 2005). The more holistic definition of mathematics anxiety accounts for the multifaceted nature of the phenomenon. For example, aside from producing performance deficits, mathematics anxiety can cause many ethnically and racially diverse groups of students to avoid participating in advanced mathematics and sciences courses (Museus, Palmer, Davis, & Maramba, 2011). Consequently, because mathematics is necessary across multiple disciplines such as science, economics, politics, social studies, genetics, and medicine, the avoidance of these courses may prevent many students from entering many science, technology, engineering, and mathematics (STEM) careers as well as other lucrative professions (Roman, 2004).

According to the National Council of Teachers of Mathematics (NCTM), "those who understand and can do mathematics will have significantly enhanced opportunities and options for shaping their futures" (NCTM, 2000, p. 5). Yet, many African American students forfeit

these opportunities, as they tend to frequently underperform on or avoid mathematics tasks (Business-Higher Education Forum, 2011; Hagedorn & DuBray, 2010). Recent research suggests that understanding mathematics identity development can help to inform research and practice to support persistence, interest, and motivation in mathematics (Cobb & Hodge, 2002), all of which are necessary for African American students as well as other students to develop resilience in the face of mathematics anxiety. Several large meta-analyses have consistently concluded that mathematics anxiety does not have a differentially larger effect on diverse students of color (Hembree, 1990; Ma, 1999). However, the majority of the studies included in prior meta-analysis consisted of large homogeneous populations of White students compared to small heterogeneous populations of underrepresented groups of racially and ethnically diverse students.

Prior Research Synthesis and Meta-Analysis

Prior research suggests that there are non-statistically significant interaction effects or combined effects between mathematics anxiety, mathematics achievement, and ethnicity (Osborne, 2001; Shannon, 2008). This indicates that mathematics anxiety does not differentiate among ethnic groups. For example, Ma (1999) concluded that the relationship between mathematics anxiety and heterogeneous and homogenous populations was essentially the same. Yet, African American or Black students were not mentioned as a study feature in any of the 27 studies included in the analysis. Instead, the results were based on heterogeneous samples comprising Latino, Thai, Native American, Australian, and Lebanese students. In a similar work, Hembree (1990) concluded that there was a non-statistically significant effect of mathematics anxiety between African American and White college students. However, of the 151 studies included in the analysis only three studies included representative numbers of African American students, all of whom were post-secondary students. Unfortunately, given the underrepresentation of African American students in colleges and universities, the results of this study may not represent the levels of mathematics anxiety that exist in the general population of African American students. Finally, in an examination of score reliabilities across studies M. Capraro, R. Capraro, and Henson (2001) concluded that results from 11 studies conducted with heterogeneous populations using the Mathematics Anxiety Rating Scale (MARS) had an inverse relationship with reliability of the instrument. Thus, as populations of participants became more diverse the reliability of the

instrument became less reliable. This is relevant because the MARS is one of the most utilized measures of mathematics anxiety and because the majority of studies that include African American participants are heterogeneous samples. This indicates that much mathematics anxiety research involving African American students may have lower reliability estimates. Nonetheless, if African American mathematics anxiety can be analyzed as an isolated variable, a better empirical understanding could emerge. The purpose of this study was to utilize the techniques of meta-analysis to summarize the effects of anxiety on mathematics achievement in K-12 African American student populations. This research synthesis was guided by the following research questions:

1. What is the magnitude or strength of the relationship between anxiety and mathematics achievement in studies with representative numbers (10% or more) of African American students?

   a. Is this relationship differentiated by the anxiety measurement instruments?

   b. Is this relationship differentiated by testing orientation (high versus low stakes testing)?

   c. Is the relationship differentiated by grade level?

Methodology

Sample of Studies

We used a three-step approach to search for relevant studies on the relationship between mathematics achievement and African American student anxiety. First a broad search of several educational research databases was conducted using the key-topic descriptors (African American, Black, mathematics, achievement, and anxiety). The specific databases searched were (a) Educational Resources Information Center, (b) Academic Search Complete, (c) PsycINFO, and (d) ProQuest. Next, utilizing the same key descriptors, meta-analysis and systematic reviews published after 1990 were located as a means to augment the initial pool of studies. Reference lists from the seminal works by Ma (1999), Hembre (1990), and Ma and Kishor (1997) were manually searched to retrieve pertinent studies.

Using the aforementioned search procedures, we located 293 studies. Initially, we screened abstracts, and then read and evaluated favorable studies with respect to the objective of this study. We included a study in this meta-analysis if it (a) was an investigation between student anxiety and mathematics achievement, (b) did

not include anxiety or mathematics interventions, (c) reported on studies conducted in K-12 educational settings, (d) included representative samples (> 10%) of non-African students racially identified as Black, and (e) reported sufficient quantitative data to calculate appropriate effect sizes. The inclusion criteria were developed to create a pool of representative studies that addressed the research questions and moderators (characteristics of studies contributing to differences in results) of mathematics anxiety effect sizes. According to Pigott (2012) identifying inclusion characteristics and moderators a priori reduces the likelihood of discovering spurious findings. Thus, this process was conducted a priori based on relevant research pertinent to the purpose of this investigation. In the current research synthesis we sought prior research and theories to inform the inclusion criteria used. For example, the population of African American students enrolled in public schools fluctuates between 10% and 16% based on grade level (Jackson & Howard, 2014). Thus, 10% was the cutoff used for inclusion of studies in this meta-analysis. Additionally, to maintain the fidelity of the results, the current investigation did not include studies that utilized mathematics and anxiety interventions because this would alter the relationship under investigation. Based on these criteria, we identified 10 individual studies representing 2,168 students for this meta-analysis.

Coding of Selected Studies

We coded each study for pertinent independent variables that captured design features as well as year and type of publication. Design features included: grade, composition of African American students presented as a percentage, sample size, instruments used to measure anxiety, and instruments used to measure achievement. Table 1 shows the coding results for each of the ten studies. The dependent variable was the correlational effect size (Pearson *r*), indicating the strength of the relationship between anxiety and mathematics achievement. Within meta-analysis three types of effect sizes are most common: (1) those used to compare means (standardized mean difference), (2) those used to measure association (correlation), and (3) those used to compare incidence rates (odds ratio) (Borenstein, Hedges, Higgins, & Rothstein, 2009). Because the majority of the studies in the present synthesis used correlation coefficients (Pearson *r*) to describe the relationship, we selected the common metric of *r* as the common effect size measure. Thus, when a study did not use Pearson *r*, the effect size was converted using the appropriate formula to a Pearson *r* for continuity. One effect size was obtained for each

study, except in the rare case that the study contained independent samples. Accordingly, where applicable, individual grade levels and separate groups of African American students in a single study were considered as an independent sample. For instance, if study A provided effect size data for 5th grade students and 8th grade students, then study A would be represented twice in the analysis.

Characteristics of the Sample

The sample consisted of ten journal articles published between 1993 and 2008. The median year of publication was 2004. Mathematics-specific anxiety was measured in six studies and general anxiety was measured in four studies. Mathematics achievement was measured using a high-stakes assessment in seven studies and a low stakes assessment in three studies. A total of 2,168 students across grades 1 through 12 participated in these studies. The largest sample was 761 with 42.1% African American students and the smallest sample was 74 with 52% African American students. Most of the studies were mixed in terms of grade and gender. The studies generated 10 independent effect sizes, all of which were negative. Table 1 on the next page presents a complete account of the characteristics of the studies included in this meta-analysis.

Statistical Procedures

We analyzed the data for this study using Comprehensive Meta-Analysis Version 2.0 (Borenstein et al., 2009). Given the correlational nature of this study, we used the product moment coefficients as the direct outcome variable. To account for the possible effects of skew, we changed all values of *r* to Fisher's *z* (Ferguson, 1981, p. 194). Then we aggregated the weighted effect sizes to form an estimate of the overall weighted mean estimate of the relationship between anxiety and mathematics achievement. Thus, we gave more weight to results that were based on larger sample sizes. We judged the statistical significance of the mean effect size by its 95% confidence interval and the application of a *z* test.

Next, we conducted a test of the homogeneity of the effect sizes. Traditionally, variation among effect sizes is determined through Hedge's *Q* test of homogeneity (Hedges & Olkin, 1985). The statistic used, Q_T, represents an extremely sensitive test of the homogeneity assumption and is evaluated via the chi-square sampling distribution. To determine whether the findings for each correlation shared a common effect size, we tested the set of effect sizes for homogeneity with the homogeneity statistic Q_T. We used the results of this test to determine

Table 1

Characteristics of Included Studies

Study	% African American	Grade Level	Anxiety Measure	Achievement Measure	N	Effect Size	CI
Good, C., Aronson, J., & Inzlicht, M. (2003)	13%	High School	Stereotype Threat	Texas Assessment of Academic Skills (TAAS)	138	$r = -0.15$	$[-.31, .02]$
Grover, R. L., Ginsberg, G. S., & Ialongo, N. (2007)	87.90%	1st Grade	Baltimore How I Feel—Young Child Version, Child Report [BHIF-YC-C]	Iowa Test of Basic Skills (ITBS)	149	$r = -0.09$	$[-.25, .07]$
Hall, C. W., Davis, N. B., Bolen, L. M., & Chia, R. (1999)	52%	5th and 8th grade	Self Reported	California Achievement Test	74	$r = -0.43$	$[-.60, -.22]$
Kellow T.J. & Jones, B.D. (2005, July 20)	36%	8th grade	State Trait Anxiety Inventory	Florida Comprehensive Assessment Test	90	$r = -0.15$	$[-.35, .06]$
Kellow, J. T., & Jones, B. J. (2008)	42%	High School	State Trait Anxiety Inventory	Applied Personnel Research Spatial Ability Test (APR)	101	$r = -0.59$	$[-.76, -35]$
McCoy, L. P. (2005)	50%	8th grade	Fennema-Sherman Mathematics Scales	North Carolina State End-of-Course Algebra I Test	107	$r = -0.75$	$[-.83, -.66]$
Pajares, F., & Kranzler, J. (1995)	20%	High School	Mathematics Anxiety Scale (MAS)	Raven's Advanced Progressive Matrices	329	$r = -0.45$	$[-.53, -.36]$
Rech, J. F., & Stevens, D. J. (1996)	100%	4th and 8th grade	Mathematics Attitude Inventory (MAI)	California Achievement Test (CAT)	251	$r = -0.11$	$[-.23, .01]$
Shores, M. L., & Shannon, D. M. (2007)	42.6%	5th and 6th grade	Test Anxiety Inventory-Revised-Mathematics	Georgia Criterion Referenced Competency Test	761	$r = -0.32$	$[-.38, -.25]$
Turner, B. G., Beidal, D. C., Hughes, S., & Turner, M. W. (1993)	100%	4th and 8th grade	Test Anxiety Scale for Children (TASC)	California Test of Basic Skills (CTBS)	168	$r = -0.36$	$[-.49, -.22]$

whether population effect sizes were relatively consistent across non-weighted effect sizes. A significant Q_T is indicative of heterogeneous results or the fact that differences in effect sizes were due to more than sampling error.

Design features can be substantial moderators of the relationship between anxiety and mathematics achievement. Thus, the differential effects of anxiety measurement instruments, type of mathematics achievement instruments, and student grade level were included in the moderator analysis. We categorized anxiety measurements dichotomously (mathematics anxiety or testing anxiety). Similarly, we categorized mathematics achievement instruments as either high or low stakes assessments. We operationally defined high-stakes assessments as state mandated assessments associated with teacher and student accountability. The third possible moderator investigated—grade level—was divided into two groups, K–8 and 9–12. Finally, we constructed a pictorial forest plot simulation of the convergence of the effect size measures using ascending percentages of African American students. This plot provides a pictorial representation of the influence of African American student composition on the effect size measures reported.

Results

In the current meta-analysis, values of r varied from -0.09 to -0.750. The mean overall value was $r = -0.36$, $p < 0.0001$. Figure 1 presents the 95% confidence intervals for the relationship between anxiety and mathematics achievement. The data presented in Figure 1

represent the magnitude and precision of the effect sizes included in the current study. The data suggest there is some variation in the effect size point estimates and levels of precision. They also provide a pictorial representation of the convergence upon the summary effect size, as the representation of African American students increases from 13% to 100%.

We conducted a test for homogeneity in the correlation coefficients using z scores, and significant heterogeneity was evident ($Q = 90.89$, df = 9, $p < 0.0001$). The results of the homogeneity test indicate that there is substantial variation in the effect sizes that should be investigated further. Appropriately, measurements of anxiety, mathematics achievement, and grade level were assessed using the between-group chi-squared statistic (Q_b) and the within group chi-square statistic (Q_w).

The reported Q_b is used to test whether the average effects of the study groupings analyzed are homogeneous. A statistically significant Q_b indicates that the grouping factor contributes to the variance in effect sizes. Thus, the grouping factors have a significant effect on the outcome measure analyzed. Similarly, the within-group chi-square statistic Q_w is comparable to the Q_T, which means that a significant value suggests the need for further exploration. The results of the moderator analysis are presented in Tables 2 – 4. The effects of anxiety measurement are summarized in Table 2. The results presented in Table 2 suggest that, although the relationship was stronger for mathematics-anxiety-related studies, the difference was not statistically significantly different at the 0.05 level. Table 3 presents the results of the influence of achievement measurement, which suggest that the relationship is slightly stronger
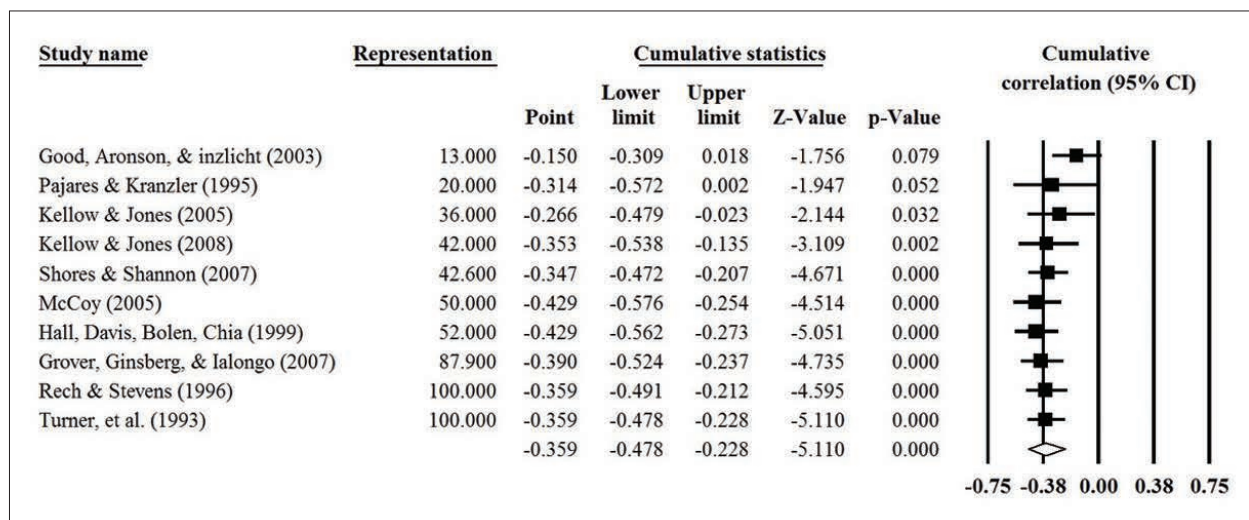
Study name	Representation	Cumulative statistics					Cumulative correlation (95% CI)
		Point	Lower limit	Upper limit	Z-Value	p-Value	
Good, Aronson, & inzlicht (2003)	13.000	-0.150	-0.309	0.018	-1.756	0.079	
Pajares & Kranzler (1995)	20.000	-0.314	-0.572	0.002	-1.947	0.052	
Kellow & Jones (2005)	36.000	-0.266	-0.479	-0.023	-2.144	0.032	
Kellow & Jones (2008)	42.000	-0.353	-0.538	-0.135	-3.109	0.002	
Shores & Shannon (2007)	42.600	-0.347	-0.472	-0.207	-4.671	0.000	
McCoy (2005)	50.000	-0.429	-0.576	-0.254	-4.514	0.000	
Hall, Davis, Bolen, Chia (1999)	52.000	-0.429	-0.562	-0.273	-5.051	0.000	
Grover, Ginsberg, & Ialongo (2007)	87.900	-0.390	-0.524	-0.237	-4.735	0.000	
Rech & Stevens (1996)	100.000	-0.359	-0.491	-0.212	-4.595	0.000	
Turner, et al. (1993)	100.000	-0.359	-0.478	-0.228	-5.110	0.000	
		-0.359	-0.478	-0.228	-5.110	0.000	

-0.75 -0.38 0.00 0.38 0.75

Figure 1. Cumulative forest plot of correlations between anxiety and mathematics achievement as the representation of African American students increases.

Table 2

Effects of anxiety measurement

Anxiety Measurement	N	r	Q_b	p
Mathematics	4(1,436)	−0.43	2.896	0.09
Non mathematics	6(702)	−0.30		

Table 3

Effects of achievement measurement

Achievement Measurement	N	r	Q_b	p
High stakes	7(1568)	−0.35	3.587	0.06
Non high stakes	3(570)	−0.39		

Table 4

Effects of grade level

Grade Level	N	r	Q_b	p
K−8	7(1579)	−0.34	6.005	0.01
9−12	3(559)	−0.41		

for low stakes mathematics assessments. However, this relationship is not statistically significantly different. Table 4 presents the effect of grade level on the relationship between anxiety and mathematics achievement for the studies in this meta-analysis. The results presented in Table 4 suggest that grade level was a statistically significant moderator of the relationship between mathematics achievement and anxiety. Specifically, the strength of relationship between anxiety and mathematics achievement is stronger in grades 9 – 12.

Conclusions

More representative research is needed to better ascertain the factors that promote and sustain mathematics anxiety in African American student populations. In particular, studies that disaggregate results based on student race are necessary for more robust estimates of this phenomenon. The results of this study diverge from the results of previous studies concerning African American students. In a meta-analysis of 34 independent studies of the relationship between anxiety toward mathematics and achievement, Ma (1999) concluded that the overall summary effect size was −.27. When compared to the −.36 summary effect size observed in the present study, the −.27 effect size from Ma (1999) is a weaker relationship. This indicates that the relationship was

stronger in the studies that included a significant representation of African American students. We should note that in the aforementioned Ma (1999) study, only mathematics anxiety scales were included, whereas in the current study, the summary effect size for studies that used only mathematics anxiety scales was −.43. This is a stronger observed relationship than the overall effect size reported for comparison earlier. Several moderators were investigated in this study to identify the possible sources of the variance in the strength of relationship between studies.

Of the three moderators investigated in this study, only grade level had a statistically significant influence on the variation in effect sizes. The results suggest that the relationship between anxiety and mathematics achievement was statistically significantly stronger for studies involving students in grades 9 – 12. This result may partially account for the lack of statistically significant difference between the high-stakes test and the non-high-stakes test. One explanation is that students in grades 9 – 12 are focused on graduation, thus the pressures of testing are more apparent. Furthermore, it is important to remember that the lack of statistically significant differences observed for the achievement and anxiety instrument moderators does not negate the practical significance of the results. Specifically, "the Q statistic and p-value address only the test of significance

and should never be used as surrogates for the amount of true variance" (Borenstein et al., 2009, p. 113). The practical significance of the anxiety moderator analysis indicates that the results are similar to prior research, which suggests that mathematics-related anxiety is more closely associated with mathematics achievement than general anxiety is (Hembree, 1990; Ma, 1999). The results of the comparison between high-stakes testing and low-stakes testing suggest that the level of the relationship was similar. However, as mentioned earlier, the lack of difference in this area could be explained by grade-level-related trends.

In summary, the results of this study suggest that anxiety has a statistically significant effect on the mathematics achievement of representative samples of African American students. This result supports the established research in this area suggesting that anxiety in general and mathematics anxiety in particular is negatively correlated with mathematics achievement (Cates & Rhymer, 2003; Maloney, Ansari, & Fugelsang, 2011; K. Ryan & A. Ryan, 2005). Furthermore, given the divergent results related to the effects on African American students' mathematics achievement presented here, more work is needed in this area to pinpoint the manifestation and the treatment of mathematics-related anxiety for this population. Specifically, since the measurement of mathematics anxiety is essential for understanding and reducing students' mathematics anxiety (Newstead, 1998), a more precise measurement of this construct with homogeneous populations of African American students is needed.

Limitations

Traditional meta-analysis methods are complicated by various limitations associated with this body of literature. First, pertinent participant descriptive data such as race or ethnicity are generally absent from many studies. Traditionally, researchers have most often investigated mathematics anxiety among White students in suburban contexts; thus, far less is known about the nature of mathematics anxiety in students from low-income backgrounds and among culturally and linguistically diverse students (August & Shanahan, 2006). Secondly, studies that do present racial frequency counts often fail to disaggregate the mathematics anxiety results by race or ethnicity. The absence of these details makes it impossible to pinpoint precise performance point estimates for African American students. Therefore researchers suggest that in order to increase meta-analytic thinking and

research quality, data should be disaggregated by race and gender whenever it is appropriate (Larke, Young, & Young, 2011). Finally, when all sample descriptive data are present, the statistical data necessary to calculate effect sizes are often absent. This is a challenge, however, for all meta-analytic work. Despite, these analytical challenges, the current structured research synthesis of the influence of mathematics anxiety on African American student achievement has explicatory significance.

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