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Young, Black, and Anxious: Describing the Black Student Mathematics Anxiety Research Using Confidence Intervals

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In this article, the authors provide a single group summary using the Mathematics Anxiety Rating Scale (MARS) to characterize and delineate the measurement of mathematics anxiety (MA) reported among Black students. Two research questions are explored: (a) What are the characteristics of studies administering the MARS and its derivatives to representative populations of Black students? (b) What is the 95% CI for the reported MA of Black students in the MARS literature? A literature search yielded 21 studies after inclusion criteria were applied. Analyses suggest that Black participants and their scores are not well represented in the current MA research using the most popular instrument the MARS. Based on available mean point estimate data, the reported MA of Black students can best be described as consistent across measurements, and population parameter estimates are between 200 and 220 on the MARS scale. Moreover, although substantial research in the area of MA exists, much work is needed to fully comprehend the nuances of Black MA and its influence on achievement in mathematics.

KEYWORDS: African American students, Black students, confidence intervals, mathematics anxiety

Mathematics literacy affords individuals the opportunity to participate fully in the community of practice. Theorists describe general identity development as the process of acquiring membership in a community of practice (Nasir, 2002; Wenger, 1998). Martin (2007) suggests that mathematics literacy in the Black student population is linked to identity construction at the intersection of their racial identity (Black) and mathematics identity (becoming a doer of mathematics). Thus, mathematics identity development for Black students is the acquisition of membership as a "doer" of mathematics while negotiating elements of their racial identity to gain full participation in the community. Subsequently, full participation in the mathematics community of learners is essential to the development of a mathemat-

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ics identity. Mathematics anxiety (MA) can serve as a major impediment to the student's participation in mathematics consistently observed in avoidance patterns. Many anxious students avoid mathematics tasks and courses to prevent exacerbating feelings of anxiety. The mounting interest in leveraging the constructs of identity development and community of practice in mathematics education research is predicated on the opportunities these constructs provide for analyzing and explaining affective aspects of mathematics learning, such as motivation, engagement, interest, anxiety, and participation (Cobb & Hodge, 2010).

Research has yet to fully examine the possible differential effect of MA on underrepresented pre-K–12 students. Specifically, given the long-standing "achievement gap" between Black and White students, it is imperative that the possible differential effect of MA on Black students[1] is addressed (National Center for Education Statistics, 2009). Historically, compared with their peers, children of color educated in urban schools disproportionately struggle with mathematics (Elias, White, & Stepney, 2014; Kellow & Jones, 2005, 2008). Given this trend, students and educators alike are under unprecedented pressure to achieve state proficiency standards and to close gaps in student achievement (Yeop Kim, Zabel, Stiefel, & Schwartz, 2006). Robust solutions, however, remain elusive. The perpetual mathematics achievement gap trends are extremely detrimental to the career aspirations and future success of Black students; therefore, if the effects of MA can be addressed in this population the ramifications would be substantial. Several educators have suggested that researchers forego the inclination to "gap-gaze" and shift their attention toward studies of between group variance and toward identifying the mathematics strength of students of color rather than continuous investigations of underachievement (e.g., Gutiérrez, 2008; Martin, Gholson, & Leonard, 2010; Stinson, 2013). These ideas support the need for more single group summaries that provide pertinent theoretical and practical knowledge to enhance instructional praxis.

Prior Research Synthesis and Meta-Analysis

Prior research suggests that non-statistically significant interaction effects exist between MA, mathematics achievement, and race and ethnicity (e.g., Hembree, 1990; Ma, 1999). These results suggest that MA does not differentiate among racial and ethnic groups. For example, in the foundational work "A Meta-analysis of the Relationship Between Anxiety Toward Mathematics and Achievement in Mathematics," Ma (1999) concluded that the relationships between MA and heterogene-

[1] Throughout this article, when referencing and reporting aggregated data on specific racial, cultural, and ethnic groups (e.g., Black students), we acknowledge the significant *within* group variation embedded (and made invisible) in such data, specifically in regards to academic achievement and performance. We also acknowledge the dangers of somehow representing such groups as monolithic across a number of demographic characteristics, which they are not.

ous and homogeneous populations were essentially the same. Yet, Black students were missing from the 27 studies included in the analysis. Heterogeneous samples included Latina/o, Thai, Native American, Australian, and Lebanese students, but Black students were not identified in the sample pool.

In an analogous work, Hembree (1990) concluded that there was a non-statistically significant effect of MA between Black and White college students. However, of the 151 studies in the analysis only three effect sizes were based on representative numbers of Black students, all of which were extracted from studies conducted in post-secondary settings.

Generally speaking, large meta-analyses have consistently concluded that MA does not have a differentially larger effect on diverse students of color. The majority of the studies included in these analyses, however, consisted of large homogeneous populations of White students compared to small heterogeneous populations of underrepresented groups of racially and ethnically diverse students. Given the underrepresentation of Black students in mathematics research literature in general, more inclusive research reporting and data presentations are necessary to better ascertain the magnitude and prevalence of MA in the Black student population.

Mathematics Anxiety Rating Scale

The Mathematics Anxiety Rating Scale (MARS) is one of the most popular and widely used instruments to assess MA. The original MARS, developed by Richardson and Suinn (1972), was a 98-item instrument that assessed levels of anxiety related to mathematics analogous tasks. Given the substantial amount of time necessary to complete the original instruments, recent derivatives of the MARS have reduced items substantially (Alexander & Martray, 1989; Suinn & Winston, 2003). These derivatives of the MARS have emerged to assess specific populations of students and to reduce the administration time, resulting from the popularity and persistence of the MARS in mathematics education over the years. Despite these changes, MARS remains one of the most popular MA instruments due to its historically consistent validity and reliability across administrations (Plake & Parker, 1982; Suinn & Edwards, 1982; Suinn, Taylor, & Edwards, 1988). Notwithstanding its strong history as a robust MA instrument, assessments with diverse populations of students are consistently less prevalent and the scores are less reliable.

In a reliability generalization study, Capraro, Capraro, and Henson (2001) concluded that across all the studies sampled, the MARS produced scores with high reliabilities, but results from 11 studies conducted with heterogeneous populations that used the MARS had a negative correlation to Cronbach's alpha reliabilities. This negative correlation is relevant because the MARS is one of the most used measures of MA, thus reliability of scores must remain stable across racially heterogeneous populations. This instability indicates that MA research involving students of color may have lower reliability estimates, but without direct inspection it is impossible to draw conclusive conclusions. Analyzing Black student MA as an isolated variable supports the ability to aggregate studies for meta-analytic thinking and can help to contextualize the mathematics performance of Black students as we move away from between-group investigations. In "Characterizing the Mathematics Anxiety Literature Using Confidence Intervals as a Literature Review Mechanism," Zientek, Yetkiner, and Thompson (2010) posit that confidence intervals (CIs) can serve as an efficient mechanism for characterizing scores on the MARS. The present study seeks to use CIs to summarize the measurement of MA using the MARS with a Black student population.

Problem Statement and Research Questions

The prevalence of MA and the magnitude of effects of MA on Black student mathematics achievement have important ramifications for subsequent student success. For example, many underrepresented students of color experience anxiety that is detrimental to their mathematics performance (Adler, 2007). These episodes can foster lower grade point averages and poor performance on college entrance exams, limiting access to many colleges and universities.

MA significantly influences cognitive functions and test performance; however, its influence on Black pre-K–12 students, albeit researched, has yet to be coherently synthesized. This phenomenon creates limitations that complicate or eliminate the application of traditional meta-analysis methods. First, pertinent participant descriptive data, such as race or ethnicity is generally absent from many studies. Second, studies that do present racial frequency counts often do not disaggregate the MA results by race or ethnicity. Third, when disaggregated sample descriptive data are present, the necessary statistical data necessary to calculate effect sizes are absent. Despite these analytical challenges, a structured synthesis of the influence of MA on Black student achievement has explicatory significance. Specifically, the use of meta-analytic thinking can help provide credence to more extensive studies of this phenomenon.

Meta-analytic thinking systematically allows researchers to benchmark their results by comparing them to prior results from analogous studies. Thus, researchers need to explicitly design and place studies in the context of the effects of prior literature (Henson, 2006). This shift in empirical thinking promotes the empirical replication of results and supports meta-analytic thinking. One analytic medium for the comparison of effect sizes is the CI. According to Thompson (2002), CIs for effect sizes are exceptionally valuable because they facilitate both meta-analytic thinking and the elucidation of intervals via comparisons with the effect intervals reported in analogous prior studies. Furthermore, Cumming and Finch (2001) suggest four reasons to use CIs:

- CIs provide point and interval information that is accessible and comprehensible, which supports substantive understanding and interpretation.
- There is a direct link between CIs and Null Hypothesis Statistical Significance Testing (NHSST).
- CIs support meta-analytic thinking focused on estimation.
- CIs communicate information about a study's precision.

In addition, sample size is a reasonable consideration when applying meta-analytic thinking to compare and evaluate, for example, technology professional development in urban mathematics classrooms. The application of meta-analytic thinking through CIs provides a lens to compare effects across large and small samples. Along with strong evidence of effect, CIs also provide two other advantages.

First, when sample sizes are considerably small, NHSST may not capitulate statistically significant results. Unfortunately, the conclusion typically associated with non-statistically significant results is that the effect is not real (Cumming & Finch, 2005). CIs, however, allow researchers to place results in a broader context to establish practical and clinical significance. Second, because all CIs report both (a) point estimates and (b) characterize how much confidence can be vested in a given point estimate (Zientek, Yetkiner, & Thompson, 2010), comparing point and interval estimates to other studies examines precision and quality of the results of a particular study across other studies.

Thus, the purpose of this study was to conduct a single group summary of studies using the MARS to characterize and delineate the measurement of reported MA within the Black student population. Two research questions guided the inquiry:

1. What are the characteristics of studies administering the MARS and its derivatives to representative populations of Black students?
2. What is the 95% CI for the reported MA of Black students in the MARS literature?

Methods

To investigate the aforementioned research questions, we conducted a literature search using the following key terms: African American/Black, mathematics anxiety, Mathematics Anxiety Rating Scale (MARS), and Math Anxiety Rating Scale (MARS). We use operational definitions to capture essence of the constructs under investigation and to help guide our consistent identification of pertinent studies. MA was operationalized as an anxious state in response to mathematics- related situations measured by self-reported surveys, physical reactions, or observations. But for the purpose of this study, we included only studies that measured MA using one of the MARS instruments. Black students were operationalized as non-immigrant pre-K–12 and post-secondary students racially self-reported as Black. Using these operational definitions as an initial guide, we used a three-step approach to search for studies that used the MARS to measure Black student MA.

We applied a broad search of several educational research databases using the key-topic descriptors (previously noted). The specific databases searched were (a) Educational Resources Information Center (ERIC), (b) Academic Search Complete (ASC), (c) PsycINFO, and (d) Educational Research Compete (ERC). Next, using the same key descriptors, we searched meta-analyses and systematic reviews published after 1990 to locate prior systematic reviews as a means to augment the initial pool of studies. We manually searched the reference list from the foundational works of Ma (1999), Hembree (1990), and Ma and Kishor (1997) to retrieve pertinent studies. Five additional studies were located using this procedure.

Using the aforementioned search procedures, we located a total of 224 studies. Study abstracts were screened initially and promising studies were read and evaluated with respect to the objective of this study. A study was included in this synthesis if it included (a) pre-K–12 or post-secondary Black participants, (b) use of the MARS or one of its derivatives, and (c) descriptive statistics. Based on these criteria, we identified 21 individual studies and 24 individual mean point estimates of MA. The complete inclusion and exclusion procedures are presented in Figure 1.

We coded each study for pertinent independent variables that captured design features as well as other pertinent characteristics. Design features included: grade, composition of Black students, sample size, MARS instruments used to measure anxiety, and Cronbach's alpha. To summarize the measurement of reported MA in the Black student population, we created a 95% CI from the baseline mean point estimates of homogenous samples of Black participants. All point estimates presented in the study were collected before participants received any treatment or intervention, and this represent the reported MA of Black students before manipulation. To maintain the fidelity of the CIs, racially heterogeneous populations had to disaggregate Black student data to be included in the CI calculations.

A 95% CI was chosen by convention, a 90% or any other level would be equally valid, but the 95% CI is a more strict measure (Zientek et al., 2010). CIs were selected because they provide point estimates for population parameters, as well as a measure of precision of these estimates that can be compared across administrations (Cumming & Finch, 2001). The point estimates are sample statistics, two of the most commonly used of which are means and effect sizes (Zientek et al., 2010). In this study, we extracted mean MARS scores across the administrations as the point estimate to summarize the mean scores.

To calculate the mean point estimates we included only studies that disaggregated and presented MARS scores for Black students. Because the 98-item MARS and Mathematics Anxiety Rating Scale for Adolescents (MARS-A) represent the oldest, most established, and most psychometrically similar instruments in present across our selected timeframe, we decided to include only these instruments in the CI calculations and presentation. From the six studies that present mean MARS scores for Black students, seven mean point estimates were extracted. Two were calculated using the MARS and five were calculated used the MARS-A. Mean MARS scores, standard deviations, and sample sizes were then used to calculate the 95% CIs.

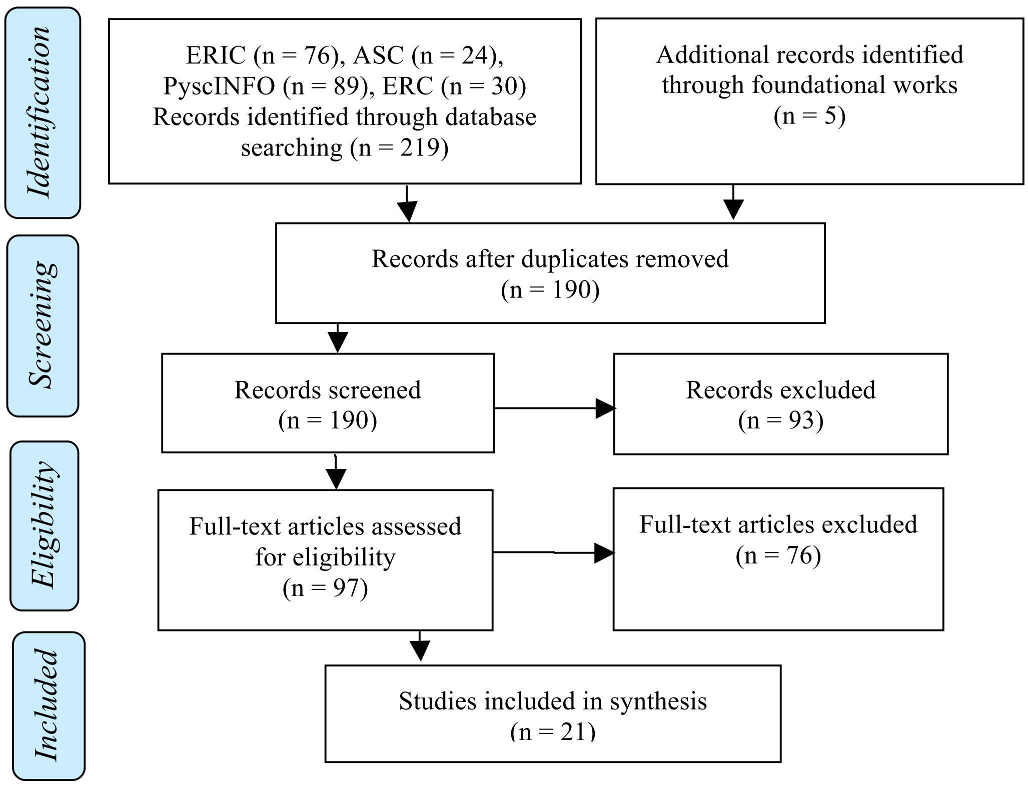

Figure 1. Literature search flow diagram for MARS.

We used the Microsoft Excel Confidence macro and the stock option to plot the intervals. The MARS and MARS-A are five point Likert scaled instruments with 98 individual items. The MA scores for each instrument are determined by the calculated sum of the individual items, thus the scores range from 98 to 490. Due to the relative underrepresentation of the MARS in the sample of scores, coupled with inconsistency in measurement specificity and parity between adolescent samples and the MARS-A instruments we combined all the 95% CI onto a single summary (see Figure 2). MARS-A point estimates were indicated by black squares and diamonds used to identify point estimates of original MARS. Using the procedures and guidelines presented in prior studies (e.g., Cumming, 2007, 2009; Zientek et al., 2010), we systematically identified a feasible estimate for the range of MARS scores represented in this single group summary. Based on visual inspection of the overlap and lack thereof between studies a reasonable inclusion ranged for the population parameter estimate of MA scores was identified.

Results

The characteristics of the studies in this review are presented in Table 1. It includes citation information, publication source, sample size, number of Black participants, and whether or not the data were disaggregated to present the mean point estimates of reported MA for Black participants.

Table 1
Characteristics of MARS Studies

Citation	Year	Source	Grade	N	N_B	B_{MARS}
Glover	1994	D	Middle	67	67	Yes
Johnson	1997	D	High	123	24	No
Kazelskis et al.	2000	A	College	321	70	No
Cox	2001	D	College	88	5	No
Hopko et al.	2002	A	College	42	2	No
Sloan et al.	2002	A	College	72	1	No
Hopko	2003	A	College	815	32	No
Hopko et al.	2003	A	College	64	2	No
Husni	2006	D	College	62	62	Yes
Miqdadi	2006	D	High	168	47	No
Baloglu & Zelhart	2007	A	College	559	81	No
Solazzo	2007	D	College	131	2	No
Gleason	2007	A	College	261	13	No
Reed	2008	D	College	84	6	No
Sprybook	2008	D	College	28	3	No
Brocato	2009	D	College	29	29	Yes
Bryant	2009	D	College	132	39	No
Jones	2009	D	High	67	67	Yes
Grassl	2010	D	College	351	55	No
Meritt	2011	D	Middle	105	105	Yes
Steiner & Ashcraft	2012	A	College	369	32	Yes

Note: D = Dissertation; A = Article; B = Black

For this pool of studies, the year of publication ranged from 1994 to 2012, with a median year of 2006. The reported representation of Black participants ranged from 0.6% to 100%, with a mean represented of 40.7% based on the ratio of the number of Black participants to non-Black participants. Dissertations were the most prevalent publication source in the pool of studies and represented approximately 62% of the included studies. Articles represented only 8 of the 21 studies or approximately 38%, and college students were the population of interest in the majority of the studies. MARS scores were not presented for Black students in 15 of the 21 studies, or approximately 71% of the studies. MARS scores for Black students were extracted from five dissertations, including homogenous populations of Black students and one article with heterogeneous participants.

Reliability scores were only presented in five of the studies reviewed in this synthesis. The reported reliabilities, however, were relatively high and ranged from .84 to .96. Of the four available MARS instruments, the Revised Mathematics Rating Scale (RMARS) was administered most often, followed by the MARS-A. A full description of each MARS instrument and its administration frequency is presented in Table 2.

Table 2
Description of MARS Survey Instruments Administrations

Description of MARS Survey	Items	Freq.
Mathematics Anxiety Rating Scale (MARS) • Measures students' anxious reaction when they do mathematics in ordinary life and academic situations (Richardson & Suinn, 1972)	98	3
Mathematics Anxiety Rating Scale for Adolescents (MARS-A) • A revised form of the MARS that involves changes in wording and substitutions appropriate for adolescents (Suinn & Edwards, 1982)	98	5
Revised Mathematics Anxiety Rating Scale (RMARS) • Revised from MARS and shorten to measure three factors: math test anxiety, numerical anxiety, and math course anxiety (Alexander & Martray, 1989)	25	9
Mathematics Anxiety Rating Scale Brief Version (MARS-Brief) • A shorter revised version of the original MARS that is comparable in construct measurement (Suinn & Winston, 2003)	30	3

Figure 2 presents the 95% CIs for Black participant performance on the MARS. The CIs allow the amount of error to be quantified from sample to sample for comparison. The level of precision in each point estimate controls the error associated with each point estimate. The width of the CI represents the precision associated with each point estimate; specifically, the smaller the width of the CI, the more precise the measurement and the wider the CI the less precise the measurement (Cumming & Finch, 2005). Furthermore, the width of the CI is directly related to the standard deviation and inversely related to sample size, two major components of measurement precision in statistics. Appropriately, if the variability (standard deviation) is small then the point estimate is more precise and likewise a larger sample size is more representative, which increases the precision of the point estimate. All of the 95% CIs presented in Figure 2 are relatively wide, indicating a lack of precision in the measurement that could be attributed to large standard errors of consistently smaller and less representative sample sizes of Black students.

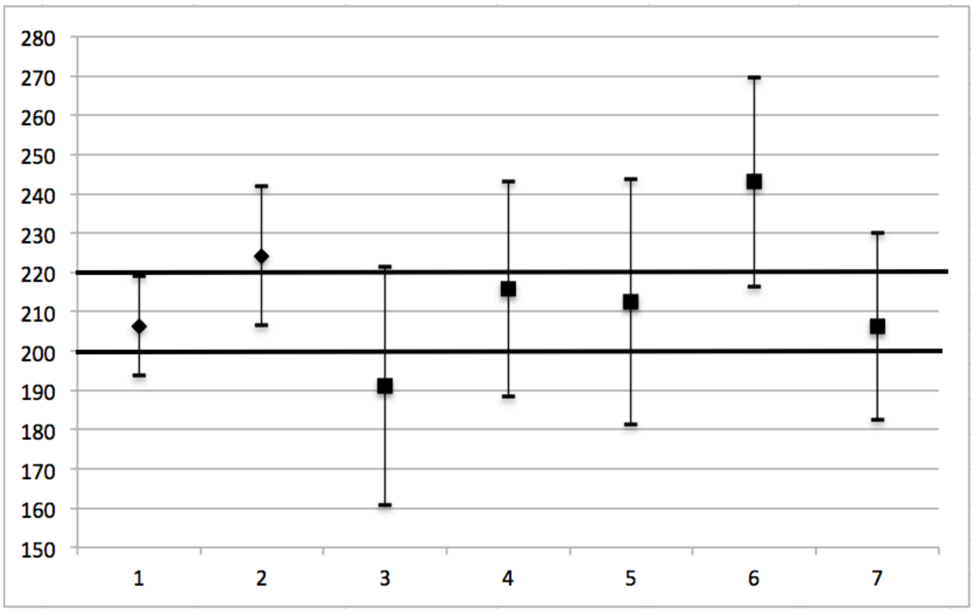

Figure 2. 95% CI for Black MA measured on the MARS.

Based in the data presented in Figure 2, the MARS scores for Black students can be best described as relatively similar in magnitude and precision. All of the confidence bands are relativity wide and all of the bands overlap at least partially with the other studies. These visuals indicate that across the observed studies there are not statistically significant differences between the mean point estimates based on the degree of overlap between the studies (Cumming, 2009). It is also worth noting that the MARS and MARS-A scores substantially overlap, indicating that the scores are fairly similar, which is expected given the similar scaling and similar participant characteristics. The position of the mean point estimates and the overlap between studies suggest that the mean point estimates for the Black population parameter is somewhere between 200 and 220. A more conservative estimate is presented given the limited number of studies and the aggregation of the MARS and MARS-A scores. An appropriate interpretation of these intervals is necessary. A

95% CI does not indicate that a point estimate correctly represents the population parameter with 95% certainty, but rather that if an infinite number of CIs are constructed, than one can be 95% certain that the population parameter is present.

Discussion

These analyses suggest that Black participants and their scores are not well represented in the current MA research utilizing the most popular instrument the MARS. Although the MARS was developed in the early 1970s, the first instance of an administration that reported the inclusion of Black participants was not until the mid 1990s. This time lapse is approximately 20 years after the development and validation of the instrument. In addition, the majority of the studies presented in the current synthesis did not include reliability scores for researcher interpretation. This review located 21 studies that included Black participants, but only 6 studies included mean MARS scores for Black students most of which were dissertation studies. Furthermore, the MARS scores for Black students were disaggregated and presented in only one study with heterogeneous participants, despite representative samples of Black students in many of the studies.

This lack of data disaggregation inhibits meta-analytic thinking as it pertains to the MA challenges of Black students. For instance, if a researcher seeks to conduct a power analysis before soliciting participants for a MA intervention in an urban school district serving a large Black population, it is nearly impossible to accurately generate a representative estimate of the number of Black students necessary to have adequate power against Type I error. One could argue that the researcher could just use the information from the general population, but given the scarcity of resources and opportunities to affect change in urban schools this is not a process that is worth leaving to chance.

Finally, based on normative MA measurements the data analyzed here suggest that MA may be slightly higher in the Black population, despite previous research that suggest otherwise. According to Suinn and Edwards (1982) normative scores for MA should range from 197.6 to 204.7. The differences between these ranges of scores are slightly higher for the Black student data analyzed. However, access to MARS point estimates from representative homogeneous samples of Black participants remains a measurement limitation.

Conclusion

MA is thought to influence learning and mastery of mathematics from an early age, but its precise developmental origins is unknown (Rubinsten & Tannock, 2010). Given that MA is one of the many elements associated with the affective domain of mathematics learning and has a well-documented detrimental effect on performance (Ashcraft, 2002; Hadley & Dorward, 2011; Harari, Vukovic, & Bailey, 2013), it is imperative that we find solutions to reduce its effects. Thus, researchers, teachers, and parents must approach MA in Black children armed with accurate and representative estimates of this construct. The results of this study suggest that, although substantial research in the area of MA exists, much more work is needed to fully comprehend the nuances of Black MA and its influence on achievement in mathematics. More non-comparative or within-group analysis is necessary to develop more representative estimates of MA in Black children.

Much of the available research uses between-group designs involving Black and White students or male and female students. One major limitation of racial- or gender-comparative designs, however, is that when group differences are found, investigators can only speculate about the causes of those differences (Dotterer, Lowe, & McHale, 2014). These activities perpetuate the trend of gap gazing and fail to yield information that is practically significant for classroom use. In addition to the need for more within-group analysis, researchers must begin to disaggregate student data by race and gender and to report individual group descriptive statistics (Capraro, Young, Lewis, Yetkiner, & Woods, 2009). The lack of reporting of sufficient statistics to calculate effect sizes for all students is a major impediment to generalizable practices for students of color, and it impedes the application of meta-analytic thinking for the purposes of supporting the mathematics teaching and learning of large populations of students in urban schools. In order to move away from the era of gap gazing, it is imperative that we as researchers and educators provide representative reports on all of the students in the participant pool. In the end, the consistent disaggregation of mathematics data by race remains elusive, and subsequently, so do robust methods to better serve urban youth in mathematics classrooms.

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