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An Update on the Abbreviated Math Anxiety Scale: Current Evidence of Reliability

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AN UPDATE ON THE ABBREVIATED MATH ANXIETY SCALE: CURRENT EVIDENCE OF RELIABILITY

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ABSTRACT

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The psychometric properties of the Abbreviated Math Anxiety Scale (AMAS) are often reassessed not using the population for which it was developed. While the scale was initially created for US undergraduate students, research has focused on testing the reliability of the AMAS within other populations, often modifying and translating them for use with children or speakers of other languages. The "replication crisis" calls into question the reliability and reproducibility of findings from many disciplines, including the social sciences, so in order for researchers to have a high degree of confidence in their data and results, measurement tools must be periodically reexamined for evidence of reliability within the population for which the scale was constructed. The purpose of the present study was to examine current evidence of construct validity and internal consistency reliability of the AMAS in a diverse and representative sample of US undergraduate students. This study utilized archival data (N = 160) of the AMAS to examine the scale's factor structure and evidence for reliability using Cronbach's alpha. The results of this study found evidence of construct validity and support for the strong reliability of the AMAS to continue to assess levels of math anxiety among current US undergraduate students.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION TO THE STUDY

Psychometric scales are an indispensable tool to measure latent psychological constructs which are inherently difficult to observe, but only to the extent there is continued evidence for the reliability of those instruments over time. The Abbreviated Math Anxiety Scale (AMAS) has been widely used by researchers and educators to study math anxiety worldwide in the two decades since it was first published by Hopko et al. in 2003, though only one known published study (Cho, 2022) has examined the evidence for its reliability in an ethnically diverse US undergraduate sample since its initial publication. The “replication crisis” in psychology has increased scrutiny on psychometric instruments as studies fail to replicate some originally reported results and those potentially false positives threaten the credibility of commonly accepted constructs and the instruments used to measure them (Maxwell et al., 2015). From 2000 to 2010, for instance, while publications increased by 40% to about 1.4 million, retractions grew tenfold from 40 to 400 per year. Retractions are now close to 700 articles per year (Hantula, 2019). While this does not implicate a large share of all publications, it only represents identified publications and is a considerable relative increase. Because math anxiety research relies heavily on rating scales that use retrospective, self-report questionnaires, it is essential that the items in those scales be periodically reassessed for evidence they continue to measure the latent construct reliably and effectively.

Consistently, higher levels of math anxiety are negatively associated with math performance and may lead to the avoidance of math coursework and careers with potentially long-term and widespread negative consequences. Researchers and educators depend on psychometrically examined instruments, such as the AMAS, to better understand math anxiety and make decisions about appropriate interventions for math-anxious individuals. As students in higher education have grown increasingly diverse in the time since the AMAS was first published, assessing current evidence of the validity and reliability of the scale with a diverse sample of US undergraduates is warranted. How do the factor loadings of the AMAS compare to the original factor loadings with data collected from a demographically diverse and representative sample of undergraduates? What is the evidence for the internal consistency reliability of the AMAS with data collected from a demographically diverse and representative sample of undergraduates? The purpose of the present study was to examine current evidence of construct validity and internal consistency reliability of the AMAS in a diverse and representative sample of US undergraduate students. This paper presents the analysis of previously collected archival AMAS data to examine the scale's factor structure for evidence of construct validity and assess internal consistency reliability using Cronbach's alpha. Periodically reevaluating the AMAS for evidence of reliability will allow researchers and educators to be more confident in the collection and application of AMAS data to better understand math anxiety and, ultimately, to design effective interventions to help students negatively impacted by it.

The archival AMAS data (N=160) utilized for this study were collected as part of an ongoing study of math anxiety and several related factors. The data were anonymized prior to being provided for analysis. Notably, the characteristics of the sample, specifically age, gender, ethnicity, and recency of academic math experience, are more representative of the current US undergraduate population than the samples in previous studies. The results of the statistical analyses, including a confirmatory factor analysis and calculating Cronbach's alpha, support the continued use of the AMAS to reliably measure math anxiety among diverse US undergraduate students. Reliably measuring an individual's level of math anxiety is an important part of developing interventions that effectively target high math anxiety and help highly math-anxious individuals overcome the negative effects of math anxiety on performance. With math anxiety as pervasive as ever and the "replication crisis" looming, assessing the AMAS for evidence of validity and reliability is as relevant now as it was when Hopko et al. (2003) developed it.

CHAPTER II

REVIEW OF THE LITERATURE

Math Anxiety

Math anxiety has been a recognized psychological construct for nearly half a century – Gough (1954) first proposed the concept of "mathemaphobia," while Dreger and Aiken (1957) coined "number anxiety" only a few years later. By 1972, Richardson and Suinn had defined math anxiety as an undesirable emotional condition that results from contact with mathematics and "interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (p. 551). Math anxiety has been reported by individuals throughout the population and tends to persist through the lifetime (Luttenberger et al., 2018; Ramirez et al., 2018; Sorvo et al., 2019). A problem of international scope, the negative effects of high levels of math anxiety can be observed across countries (Foley et al., 2017) and are wide-ranging, including decrements in performance on math assessments (Dowker et al., 2016), negative attitudes and the avoidance of math-related coursework and careers (Choe et al., 2019; Daker et al., 2021; Hembree, 1990), measurable physiological responses such as elevated heartrate and cortisol levels (Pletzer et al., 2015) and neural activation similar to experiences of physical pain (Lyons & Beilock, 2012). While some academic anxiety is associated with improved performance and levels of math anxiety fluctuate from country to country, high levels of math anxiety are typically negatively associated with performance (Barroso et al., 2021), including on internationally administered standardized tests (Foley et al., 2017). A common, though not universal, finding in math anxiety research is that women report higher levels of math anxiety than men (Sarfo et al., 2020), which may partly explain or relate to why women are less likely to pursue math-focused academic and professional fields (Perez-Felkner et al., 2017). To better understand math anxiety and the negative effects it can have on students' math experiences and attitudes, it is important to measure math anxiety accurately and reliably.

Measuring Math Anxiety

Historically, math anxiety has been studied using retrospective self-report measures that use Likert-type scales for rating perceived anxiety in various situations and contexts related to mathematics. These scales have been widely used to collect math anxiety data used to examine the relationship between math anxiety and several related constructs, such as math performance, math self-concept, and math self-efficacy (Bhowmick et al., 2017; Jameson & Fusco, 2014; Lee, 2009). While individuals of all ages can experience math anxiety, measures of math anxiety are typically administered to those from a population not too dissimilar to the one used to develop the scale. For instance, the Children's Anxiety in Math Scale (Jameson, 2013) was developed specifically for use with children because other available instruments had been initially developed for use with undergraduate students and only later adapted. High math anxiety, for example, is often defined as scoring more than one standard deviation above the mean (Ashcraft, 2002). To assess math anxiety in this way requires a great deal of confidence that the instrument measures math anxiety accurately and reliably across the population in question. Periodically, math anxiety rating scales are reexamined to assess current evidence of validity and reliability, often with the goal of improving the scale by revision or deletion of irrelevant items. When these revisions are concerned with abbreviating the scale by eliminating items or modernizing their language, they can make the scale more reliable and easier to use. Abbreviated measures of math anxiety are also desirable because they take less time to administer. Moreover, shorter measures may be less prone to introduce systemic measurement error because they are simpler for participants and researchers to use. Additionally, fewer items can reduce item overlap.

Math anxiety has been measured with self-rating scales at least since Richardson and Suinn (1972) developed and published the first one with accompanying psychometric data – the 98-item Math Anxiety Rating Scale (MARS). Since, researchers have attempted to abbreviate math anxiety scales to make them more accessible, reliable, and convenient to use. Revisions by Plake and Parker (1982) to the original MARS resulted in the 24-item Math Anxiety Rating Scale-Revised (MARS-R). Nearly two decades later, Hopko (2003) used confirmatory factor analysis (CFA) to explore the psychometric properties of the MARS-R and found evidence that suggested the MARS-R, as it was, was no longer a valid and reliable measure of math anxiety, and that the number of items could be reduced to 12 to improve it. Considering the poor fit the MARS-R exhibited in explaining math anxiety, Hopko et al. (2003) developed and published a separate short-form math anxiety scale that had similar psychometric properties to what had been reported for longer-form scales in use at the time. The Abbreviated Math Anxiety Scale (AMAS) consists of nine items, many of them borrowed from the 12 retained items of the MARS-R, assessing math anxiety using a Likert-type rating scale (*1*="low anxiety" - *5*="high anxiety"). Hopko et al. (2003) used three independent samples to develop and validate the AMAS: a first sample to develop and select the items with an exploratory factor analysis; a second sample to establish concurrent, convergent, and divergent validity evidence by comparing the AMAS to other accepted measures of math anxiety; and a third sample to explore the internal consistency (α=.90) and reliability evidence through a confirmatory factor analysis. The specific directions of the AMAS are, "Please rate each item below in terms of how anxious you would feel during the event specified” (see Appendix A). These directions are followed by a series of statements that are to be rated. The response options for this Likert-type scale range from *1* to *5*, corresponding, respectively, to the categories “low anxiety,” “some anxiety,” “moderate anxiety,” “quite a bit of anxiety,” and “high anxiety.” No items are reverse coded. With nine items and one to five points possible per item, potential scores range from 9 to 45. The reduction in items from the original 98-item MARS to the current nine-item AMAS represents an elimination of more than 90% of the items while improving psychometric properties, such as internal consistency reliability.

As math anxiety is a global phenomenon, math anxiety rating scales continue to be adapted for use in populations other than those used to develop them. Since its publication by Hopko et al. in 2003, the AMAS has been translated into at least seven other languages and restudied for evidence of reliability and validity in those languages. The AMAS has been successfully adapted for use with British elementary school children (Carey et al., 2017) and has been translated into Persian (Vahedi & Farrokhi, 2011), Italian (Caviola et al., 2017; Primi et al., 2014), Polish (Cipora et al., 2015), Spanish (Brown & Sifuentes, 2016; Martín-Puga et al., 2022), German (Schillinger et al., 2018), Serbian (Milovanović & Kodžopeljić, 2018), and Arabic (Megreya et al., 2023). The results of these studies all support the continued use of the AMAS to assess math anxiety across a range of ages, genders, education levels, languages, and geographic regions. The prevalence of math anxiety across cultures and countries suggests there is continued interest in the psychometric properties of the AMAS some 20 years since its initial publication. For researchers and educators to have confidence in the use of instruments such as the AMAS amidst the so-called “replication crisis,” periodic reassessments are necessary (Hantula, 2019; Maxwell et al., 2015). Only once since its publication was the AMAS restudied in a diverse sample of US undergraduate students and the overall results of that study (Cho, 2022) suggest that it is still a reliable measure of math anxiety among US undergraduates.

Subconstructs of Math Anxiety

Math anxiety is distinct from other academics-related anxieties, such as test anxiety, though many of the negative consequences, such as impaired working memory and avoidant behaviors, are common to both (Ashcraft, 2002; Devine et al., 2012). One proposed aspect of math anxiety is the anxiety around learning, while another is concerned with the anxiety in response to assessment. Together, these two subconstructs are thought to reflect the complex nature of math anxiety. The AMAS contains two subscales that correspond to the two proposed subconstructs of math anxiety that Hopko et al. observed and sought to measure: Learning Math Anxiety (LMA) and Math Evaluation Anxiety (MEA). LMA is concerned with anxiety that accompanies learning experiences, typically in the classroom and with course materials, while MEA is concerned with anxiety that accompanies taking math tests and other forms of evaluation and assessment in mathematics. Previous research has indicated that math anxiety may manifest separately in response to these different situations and their unique demands, and negatively impact various aspects of the learning process (Hopko, 2003; Hopko et al., 2003; Plake & Parker, 1982).

While highly correlated, LMA and MEA emerged as distinct factors in both Hopko et al.'s initial study (2003) and Cho's (2022) study. Though Hopko et al.'s (2003) sample was 93% White and Cho's (2022) sample was more diverse and 69% Hispanic, they both found similar factor loadings using the established two-factor model of math anxiety. Table 1 compares the original factor loadings that Hopko et al. (2003) found for each of the nine items with those obtained by Cho (2022). Higher factor loadings indicate more alignment of that item with its corresponding factor. Factor loadings were similar for both Hopko et al.’s (2003) and Cho’s (2022) studies, except for item 1, “Having to use tables in the back of mathematics book,” which performed moderately compared to the original study. Cho (2022) addressed this concern briefly but did not offer an explanation as to why the item performed worse than in Hopko et al.’s (2003) original study. In fact, item 1 was the lowest factor loading in the original study as well. Hopko et al. (2003) found that together the two factors, LMA and MEA, explained 70% of total variance in math anxiety scores. Historically, many math anxiety measures have differentiated subconstructs measured by embedded subscales, and the idea that anxiety associated with learning math is different from anxiety associated with being evaluated in math was well established in some of the earliest versions in this lineage of scales (Hopko, 2003; Hopko et al., 2003; Plake & Parker, 1982).

Table 1

Factor Loadings Reported in Relevant Studies

	Hopko et al., 2003		Cho, 2022	
	LMA	MEA	LMA	MEA
AMA1. Having to use the tables in the back of a mathematics book.	**.52**	.35	**.36**	-
AMA2. Thinking about an upcoming mathematics test one day before.	.27	**.86**	-	**.77**
AMA3. Watching a teacher work an algebraic equation on the blackboard.	**.77**	.35	**.75**	-
AMA4. Taking an examination in a mathematics course.	.22	**.89**	-	**.82**
AMA5. Being given a homework assignment of many difficult problems which is due the next class meeting.	.31	**.66**	-	**.61**
AMA6. Listening to a lecture in mathematics class.	**.86**	.25	**.84**	-
AMA7. Listening to another student explain a mathematics formula.	**.82**	.17	**.72**	-
AMA8. Being given a “pop” quiz in a mathematics class.	.29	**.84**	-	**.78**
AMA9. Starting a new chapter in a mathematics book.	**.75**	.26	**.75**	-

Note. Boldface values indicate an item’s designated factor. LMA=Learning Math Anxiety; MEA=Math Evaluation Anxiety. Cho (2022) did not report non-designated factor loadings.

Translations of the Abbreviated Math Anxiety Scale

Math anxiety is a global phenomenon, and there is widespread interest in measures of math anxiety across languages, cultures, and age groups. The earliest published example of the AMAS being translated into another language is by Vahedi and Farrokhi into Persian in 2011. The Persian version of the AMAS was established using a confirmatory factor analysis (CFA) as evidence of construct validity and internal consistency reliability was high. The Persian version of the AMAS was shown to be invariant across genders. As with the AMAS's initial development in English, the Persian version of the scale was intended for use with Persian undergraduate students (Vahedi & Farrokhi, 2011). A few years after that first translation and adaptation into Persian, Primi et al. (2014) translated the AMAS into Italian and found similar evidence of reliability and validity of the AMAS with high school and college students in Italy. Their paper analyzed the factor structure of the AMAS with Italian high school and college students and tested the invariance of the scale across educational levels and genders. Their overall findings supported the use of AMAS with Italian students across ages, genders, and educational levels (Primi et al., 2014).

In 2018, Schillinger et al. translated the AMAS into German (referred to as AMAS-G) and examined for reliability and validity evidence for use with German university students. As in studies with Persian and Italian students, the AMAS-G was shown to be a reliable and valid tool to assess math anxiety among students in non-English languages (Schillinger et al., 2018). Similar evidence in support of the construct validity and internal consistency reliability of the AMAS has been published in several other translations and adaptations of the scale. Evidence has been established that the AMAS can be translated into other languages and demonstrate evidence of continued reliability and validity, but with only one other recent published study

(Cho, 2022) of the psychometric properties of the AMAS in a diverse US undergraduate sample, it is still relevant to examine the evidence for the enduring reliability of the scale in the intended population.

The AMAS has been a valuable tool in math anxiety research but until recently had not been analyzed for updated reliability information in a US English-speaking undergraduate sample. Cho's (2022) important work, which was published during data analysis for the current project, reveals the continued strength of the AMAS as a tool to assess math anxiety. The current work seeks to supplement Cho's findings of the validity and reliability of the AMAS with an even more representative sample of US undergraduates. This work is guided by the following research questions:

Q1 How does the factor structure of the AMAS compare to the original factor structure with data collected from a demographically diverse and representative sample of undergraduates?

Q2 What is the evidence for the internal consistency reliability of the AMAS with data collected from a demographically diverse and representative sample of undergraduates?

CHAPTER III

METHODOLOGY

Archival Data

Data were provided by Dr. Molly Jameson's research lab (see Appendix B for IRB approval). The dataset included data collected between 2016-2017 from several previous studies on math anxiety and related social and cognitive factors. The available data include item-level information for AMAS math anxiety ratings, math assessment scores, results of a both a verbal and a numerical working memory test, demographic information, academic major and minor, cumulative GPA, math attitudes, and time since last math class. Data were collected through IRB-approved research projects and have been anonymized for use as archival data for analyses. Data were available for 160 individuals. These data come from 101 (63%) women, 58 (36%) men, and 1 (<1%) transgender individual. These gender proportions are largely representative of the current US undergraduate population: 68.6% women, 31.4% men (National Center for Education Statistics, 2021-2022) and similar to the sample characteristics of Hopko et al. (2003) and Cho (2022), who sampled 1,239 (729 or 59% women and 510 or 41% men) and 376 participants (248 or 66% women and 128 or 34% men), respectively. Ages provided in the available archival data ranged from 18 to 38 (M=19.53, SD=2.85), whereas Hopko et al. (2003) and Cho (2022) reported their participants' mean ages as 19.6 (SD=3.0) and 21.08 (SD=5.42) years old, respectively. The self-reported cumulative GPAs of the archival data ranged from .79 to 4.00 (M=2.84, SD=.69). Most individuals (86.3%) reported taking a math class within the prior year, so their experience with math can be considered recent (see Table 2). GPA and prior math experience data were either not collected or not reported by Hopko et al. (2003) or Cho (2022). Research from Jameson (2020) suggests time since last math class is an important and recurring theme in explaining the math anxiety of adult undergraduate learners as the recency of an academic math experience may play a role in how an individual understands and rates their math anxiety. Importantly, the ethnic makeup of the available archival data is more like the current US population than either the original sample used by Hopko et al. (2003) to develop the AMAS or the study by Cho (2022) (see Table 3). Taken together, the gender, ethnic, and recency of last math experience of the archival data are highly representative of the current US undergraduate populations, which have become more diverse since the initial publication of the AMAS. Because the original study was predominantly White and the Cho study was majority Hispanic/Latinx, it is still worthwhile to examine the psychometric properties of the AMAS in a more representative sample of US undergraduates.

Table 2

Recency of Math Experience

	Frequency	Percent
Current	45	28.1
Last Semester	38	23.8
Last Year	55	34.4
2-5 years ago	21	13.1
10+ years ago	1	.6
Total	160	100.0

Note. Responses to the item: “When was your last math class?”

Table 3

Ethnicity of Archival Data, Relevant Studies, and the Nation

Percent	Current Study	Hopko	Cho	US*	College**
White	59.4	91	9	59.3	48.1
Black	8.1	5	10	13.6	12.0
Latinx	18.1	2	69	16.9	18.9
Asian	3.8	1	11	6.1	6.9
Biracial	8.1	0	0	2.1	3.9
Other	2.6	1.1	1	1.6	10.2
Total	100.0	100.0	100.0	100.0	100.0

Note. *Estimates based on United States Census Bureau QuickFacts, 2020. **Estimates based on National Center for Education Statistics, 2021-2022.

Procedures

Data for the current study is anonymized, archival data that was previously collected from undergraduate students recruited for various IRB-approved research studies in Dr. Jameson's laboratory. All participants individually provided informed consent and, depending on the research study, completed a variety of measures and surveys. All participants completed the AMAS as part of their research participation. Prior to providing the dataset for the current study, Dr. Jameson removed any identifying information from the data.

CHAPTER IV

RESULTS

Descriptive Statistics

List-wise deletion was used to remove the data of three individuals with missing data to ensure all analyses were conducted with only complete data (*N*=157). With nine items on the AMAS and five points possible per item, potential scores range from 9 to 45 (*M*=25.76, *SD*=7.08). The average item score across all items was 2.86 (*SD*=1.35). For the 4-item MEA and 5-item LMA subscales, participants reported higher average item levels of MEA (*M*=3.69, *SD*=1.20) than LMA (*M*=2.20, *SD*=1.06). Item-level means and standard deviations are presented in Table 4 and grouped by designated factor.

Table 4

Item Statistics

	M	*SD*
Learning Math Anxiety		
AMA1	1.97	1.000
AMA3	2.17	1.049
AMA6	2.15	1.073
AMA7	2.32	1.098
AMA9	2.39	1.061
Math Evaluation Anxiety		
AMA2	3.58	1.282
AMA4	3.73	1.211
AMA5	3.54	1.169
AMA8	3.92	1.109

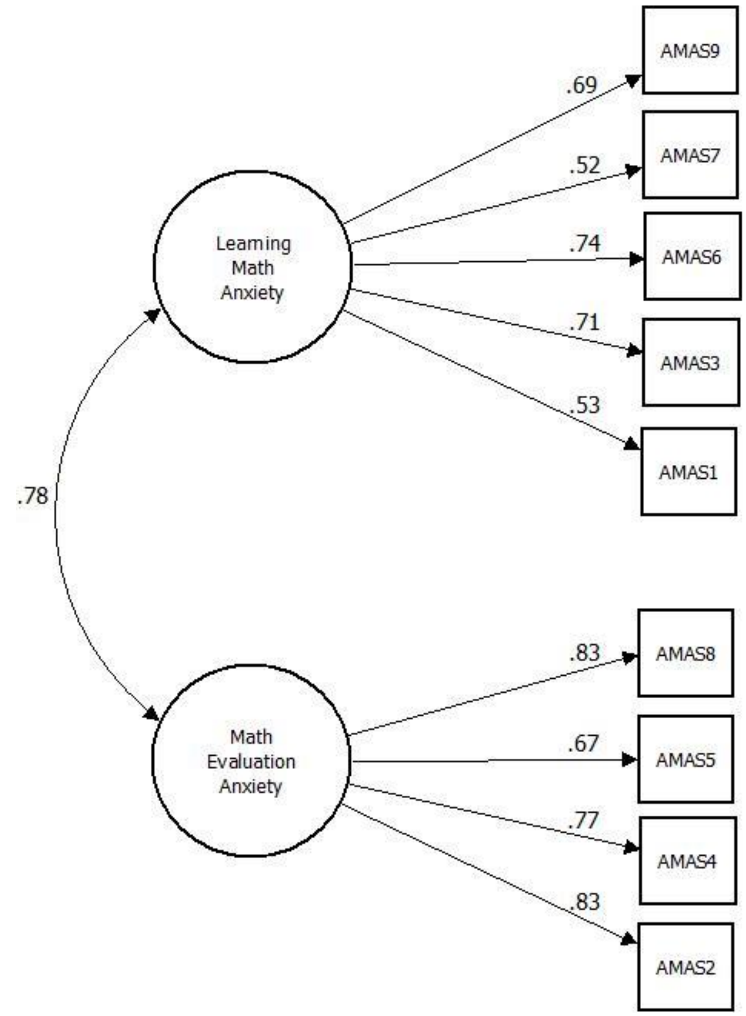
Note. *N*=157.

Confirmatory Factor Analysis

To assess evidence of construct validity, a confirmatory factor analysis (CFA) was conducted to establish the factor loadings (shown in Figure 1). While all LMA items were slightly right-skewed and all MEA items were slightly left-skewed, skewness was low for all individual items and there was little skew of the overall dataset (.14). To accommodate a lack of perfectly normal distribution for each item, the diagonally weighted least squares (DWLS) estimator was used (Xia & Yang, 2019), which provides the scaled chi-square (χ^2) test statistic with Satorra-Bentler adjustments. Robust versions of the Root Mean Square Error of Approximation (RMSEA; Steiger, 1990), Comparative Fit Index (CFI; Bentler, 1990), Tucker-Lewis Index (TLI; Tucker & Lewis, 1973), and Standardized Root Mean Square Residual (SRMR) were used to assess model fit adequacy. Since the most parsimonious explanation is desirable, differential fit of one- and two-factor models was analyzed. The CFA and other statistical analyses were performed with the lavaan package (v. 0.6.13) (Rosseel, 2012) in R (*R: The R Project for Statistical Computing*, 2022). Based on published guidelines from Hu and Bentler (1999) and Kline (2015), RMSEA less than .10, SRMR less than .08, and CFI and TLI greater than .90 indicate adequate model fit. The factor loadings in this study are comparable to those found by Hopko et al. (2003) and Cho (2022).

Figure 1

Path Analysis of the Two-Factor AMAS Model



Note. *N*=157.

One-Factor Versus Two-Factor Model

Fit indices for a one-factor model suggest poor fit (RMSEA=.182, CFI=.827, TLI=.769, SRMR=.076), whereas the fit indices for a two-factor model indicate a better fit (RMSEA=.128, CFI=.918, TLI=.887, SRMR=.055). The indices of fit generally indicate support for a two-factor model, confirming a result consistently found in research involving the AMAS, although there may be some misspecification of the model based on these fit indices. Based on the available information and the original structure of the AMAS, two factors were selected. The factors LMA and MEA explain 49.7% and 11.7% of total variance, respectively. This analysis found that 61.4% of total variance was explained by the two factors, whereas Hopko et al. (2003) found these two factors explained 70% of total variance. The factor loadings for the current study are presented in Table 5 alongside the factor loadings found by Hopko et al. (2003) and Cho (2022). The factor loadings found in this study were comparable to those found by previous research. All standardized loading estimates were statistically significant and factor loadings were strong overall, though two items, AMA1 and AMA7, exhibited more moderate factor loadings (<.6). Table 6 presents the fit indices of the one-factor (M1) and two-factor (M2) models of the AMAS. As previous literature suggests, a two-factor model of math anxiety better fits the data collected through the administration of the AMAS. Comparable factor loadings and a more adequate two-factor fit with a diverse and representative sample indicate support for the construct validity of the AMAS and that it does measure math anxiety among current US undergraduate students.

Table 5

Factor Loadings Reported in Relevant Studies and the Current Study

	Hopko et al., 2003/Cho, 2022/Current Study *Factor Loadings*	
	Learning Math Anxiety	*Math Evaluation Anxiety*
AMA1. Having to use the tables in the back of a mathematics book.	**.52/.36/.53**	—
AMA2. Thinking about an upcoming mathematics test one day before.	—	**.86/.77/.83**
AMA3. Watching a teacher work an algebraic equation on the blackboard.	**.77/.75/.71**	—
AMA4. Taking an examination in a mathematics course.	—	**.89/.82/.77**
AMA5. Being given a homework assignment of many difficult problems which is due the next class meeting.	—	**.66/.61/.67**
AMA6. Listening to a lecture in mathematics class.	**.86/.84/.74**	—
AMA7. Listening to another student explain a mathematics formula.	**.82/.72/.52**	—
AMA8. Being given a “pop” quiz in a mathematics class.	—	**.84/.78/.83**
AMA9. Starting a new chapter in a mathematics book.	**.75/.75/.69**	—

Note. Boldface values indicate an item’s designated factor. Non-designated factor loadings are not reported.

Table 6

Model Comparison and Fit Indices

AMAS Model	χ^2 (*df*)	CFI	TLI	SRMR	RMSEA (90% CI)
M1: One-factor	34.036 (27)	.827	.769	.076	.182 (.148-.218)
M2: Two-factor	45.330 (26)	.918	.887	.055	.128 (.090-.166)

Note. Chi-square (χ^2) is scaled and fit indices are robust versions.

Internal Consistency

The reliability of the AMAS (Cronbach's alpha α) was high for the overall scale (α=.87). In fact, there is no item that could be deleted from the scale to increase Cronbach's alpha, suggesting that the AMAS may have as few items as it can to work as intended. Alpha if deleted for some items was equal to overall alpha, but no single item could be removed to increase Cronbach's alpha (see Table 7). Two items, however, AMAS1 ("Having to use the tables in the back of a mathematics book") and AMAS7 ("Listening to another student explain a mathematics formula"), both from the lower-rated LMA subscale, could be removed without lowering overall reliability. Cronbach's coefficient alpha of internal consistency reliability was lower for the two subscales, LMA (α=.78) and MEA(α=.86), than for the overall scale (α=.87). In this study, the AMAS exhibited strong evidence of internal consistency reliability with a diverse and representative sample.

Table 7

Cronbach's Alpha if Item Deleted

	Alpha if deleted
AMA1. Having to use the tables in the back of a mathematics book.	.870
AMA2. Thinking about an upcoming mathematics test one day before.	.847
AMA3. Watching a teacher work an algebraic equation on the blackboard.	.857
AMA4. Taking an examination in a mathematics course.	.852
AMA5. Being given a homework assignment of many difficult problems which is due the next class meeting.	.859
AMA6. Listening to a lecture in mathematics class.	.854
AMA7. Listening to another student explain a mathematics formula.	.871
AMA8. Being given a "pop" quiz in a mathematics class.	.847
AMA9. Starting a new chapter in a mathematics book.	.858

Note. Cronbach's alpha for overall scale reliability is α=.87.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Discussion

The purpose of the present study was to examine current evidence of construct validity and internal consistency reliability of the AMAS in a diverse and representative sample of US undergraduate students. The overall findings indicated the AMAS remains a valid and reliable measure of math anxiety in diverse US undergraduate populations. While some indices of fit suggested the two-factor structure of the AMAS is adequate, others indicated a less adequate fit. No single indicator of fit suggested a poor fit of the two-factor model, and all indices of the two-factor model were more adequate than those of the one-factor model. The factor loadings found in this study were comparable to the those found by Hopko et al. (2003) in the development of the AMAS. This evidence of construct validity suggested the AMAS measures math anxiety even when used with a diverse and representative sample of students. The scale's internal consistency reliability remained high (α=.87) with a diverse sample, but reliability could possibly be preserved while deleting one or more items, specifically AMA1 and AMA7. Alternatively, these items could be improved by revising them. The AMAS is widely and frequently used in math anxiety research, though only one known study (Cho, 2022) assessed the reliability of the AMAS among undergraduate college students in the US since it was developed by Hopko et al. in 2003. This study used archival AMAS data from a diverse sample of US undergraduate students to examine the evidence that the AMAS continues to be a valid and reliable measure of math anxiety and its component factors. Math anxiety is associated with negative outcomes in mathematics and adversely affects math-related career choices, and it remains a concern for educators and researchers since it was identified and defined more than a half-century ago.

Developing effective interventions for math anxious students likely depends, in part, on being able to accurately identify individuals with high levels of math anxiety. And to a further extent, identifying whether an individual's math anxiety is related more to the learning process or to the evaluation process may be a valuable tool for understanding what interventions may successfully alleviate the most negative impacts of high math anxiety. If there is a threshold at which math-specific anxiety interferes with math performance, by disrupting working memory or creating math-avoidant behaviors, for instance, then correctly assessing an individual's level of math anxiety may be crucial to design interventions that positively impact math-anxious learners. There must be a high degree of confidence that the scale indeed measures the latent construct and does so reliably across subsections of the population in question. Periodically reassessing whether the AMAS effectively and reliably measures math anxiety in the current population of diverse US undergraduate students is necessary to have confidence in the application of those AMAS scores to inform future research, actions, and efforts to reduce the negative impact of math anxiety on performance and its differential and detrimental effect on academic course selection and career choices among women and underrepresented ethnicities. The AMAS was developed by Hopko et al. (2003) with a predominantly (91%) White sample and restudied by Cho (2022) with a majority (69%) Hispanic sample. This study sought to examine the AMAS with a more representative sample of US population and US undergraduate demographics. The results indicate that the AMAS continues to be a valid and reliable measure of math anxiety across a diverse US undergraduate population. This is an important consideration as US higher education is increasingly diverse.

As the AMAS's name suggests, an abbreviated measure is desirable, but only to the extent that it retains robust psychometric properties among a wide variety of individuals. Perhaps a shorter version of the AMAS could prove to be valid and reliable, but only follow-up research with a larger, diverse sample will provide the confidence needed to modify the scale. Perhaps a completely new measure of math anxiety could be developed that would exceed the psychometrics of the current one, but any such measure should be developed with a diverse sample, representative of the intended population and should demonstrate convergent validity with the AMAS. Over the 20 years since the AMAS was first published, it has been restudied numerous times in other countries and languages with strong evidence of validity and reliability, but only once in a US undergraduate sample. The items in this analysis match the same subscale constructs as Hopko et al.'s (2003) original study and Cho's (2022) restudy, providing evidence for the enduring construct validity of the measure. The internal consistency reliability also remains high. Taken collectively, the preponderance of the evidence indicates that the AMAS continues to perform satisfactorily for assessing math anxiety among a diverse population of US undergraduates.

Limitations of the Current Study and Future Research

Several limitations of the current study should be addressed in any future study. The principal limitation of this study is that it used a smaller sample than most of the studies of reliability and validity of the AMAS, both among US undergraduate and translated studies. Larger sample sizes coupled with representative, diverse sample demographics would make for more conclusive and generalizable results. Another limitation of the current study is that it did not investigate evidence for convergent validity, such as comparing the AMAS with another similar measure of math anxiety or by demonstrating a negative correlation between math anxiety and math performance. Additionally, future studies with larger samples should investigate the ethnic invariance of the AMAS, as it has been widely used across languages and cultures and shown to be invariant across genders and education levels.

Future research should be concerned with periodically reexamining the reliability and validity evidence of the AMAS to have ongoing confidence in the use of the AMAS to study math anxiety. Research should continue to investigate the scale's psychometric properties and new and more relevant items should be developed and introduced into the scale as needed to maintain its relevance. For instance, this study suggests that items 1 or 7, both related to Learning Math Anxiety (LMA) rather than Math Evaluation Anxiety (MEA), could be removed without negatively impacting the scale's internal consistency reliability, however a larger sample should be obtained before hastily doing so simply to save space and time in the administration of the AMAS. Since LMA items represent a smaller share of the variance of math anxiety, it may be the case that LMA is not as strong a predictor of math anxiety and MEA could serve as a proxy for math anxiety. Indeed, for many students, it is math anxiety's impact on working memory and, ultimately, on math test scores that has the most negative consequences for their academic and professional trajectories. Another potential line of research is the math anxiety of graduate students as it is relatively understudied and mathematics in the form of statistics is ubiquitous in graduate programs. Additionally, math anxiety as it relates to subdiscipline (e.g. statistics, algebra, geometry) is not frequently studied except insofar as research has investigated the timing and onset of math anxiety related to grade level.

With an increasing reliance on digital learning materials and the ability to search the internet, it could be that "Having to use tables in the back of a math book" is no longer as relevant as it was when the AMAS was developed in 2003. Only a larger sample will provide the evidence needed to make that determination with confidence. Moreover, future research should investigate the evidence for convergent validity as the negative relationship between math anxiety and math performance has been well-established. Another direction for future research is to establish the link more fully between math-specific academic self-concept and self-efficacy with math anxiety, performance, and working memory. Perhaps self-concept and self-efficacy mitigate some of the negative consequences of math anxiety on performance and future research can investigate this relationship.

Conclusion

Math anxiety is negatively associated with math performance across ages, genders, languages, and education levels, and researchers and educators rely on psychometrically examined instruments to study it. While the "replication crisis" is a significant concern for researchers, the evidence presented in this present study suggests the AMAS is still a valid and reliable measure of math anxiety, including among a diverse and representative sample of US undergraduate students. The factor structure of the AMAS suggested that the items still assess the construct of math anxiety, and the internal consistency reliability was high. Researchers can continue to use the AMAS with a high degree of confidence that the items still validly and reliably measure math anxiety. Indeed, the first step in developing interventions aimed at alleviating the negative effects of math anxiety on performance is to measure math anxiety accurately and reliably across the population and not to assume that a commonly used measure is a valid and reliable one. After 20 years of widespread use, the AMAS remains an important and reliable tool in math anxiety research among current US undergraduates.

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APPENDIX A

ABBREVIATED MATH ANXIETY SCALE

Please rate each item below in terms of how anxious you would feel during the event specified.

	Low Anxiety	Some Anxiety	Moderate Anxiety	Quite a bit of Anxiety	High Anxiety
1. Having to use the tables in the back of a mathematics book.	1	2	3	4	5
2. Thinking about an upcoming mathematics test one day before.	1	2	3	4	5
3. Watching a teacher work an algebraic equation on the blackboard.	1	2	3	4	5
4. Taking an examination in a mathematics course.	1	2	3	4	5
5. Being given a homework assignment of many difficult problems which is due the next class meeting.	1	2	3	4	5
6. Listening to a lecture in mathematics class.	1	2	3	4	5
7. Listening to another student explain a mathematics formula.	1	2	3	4	5
8. Being given a “pop” quiz in a mathematics class.	1	2	3	4	5
9. Starting a new chapter in a mathematics book.	1	2	3	4	5

APPENDIX B

INSTITUTIONAL REVIEW BOARD APPROVAL

UNIVERSITY OF
NORTHERN COLORADO

Institutional Review Board

DATE:	November 21, 2018
TO:	Edward Worden
FROM:	University of Northern Colorado (UNCO) IRB
PROJECT TITLE:	[1352609-1] Examining the Reliability and Validity Evidence of the Abbreviated Math Anxiety Scale
SUBMISSION TYPE:	New Project
ACTION:	APPROVAL/VERIFICATION OF EXEMPT STATUS
DECISION DATE:	November 21, 2018
EXPIRATION DATE:	November 21, 2022

Thank you for your submission of New Project materials for this project. The University of Northern Colorado (UNCO) IRB approves this project and verifies its status as EXEMPT according to federal IRB regulations.

We will retain a copy of this correspondence within our records for a duration of 4 years.

If you have any questions, please contact Nicole Morse at 970-351-1910 or nicole.morse@unco.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records.