The Abbreviated Math Anxiety Scale (AMAS)

Construction, Validity, and Reliability

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*Psychometric properties of mathematics anxiety measures have not adequately been studied. Using a large sample size (*N *= 1,239), the authors developed an abbreviated math anxiety measure, examined its psychometric properties, and assessed the generalizability of the model across samples. Exploratory factor analysis yielded a nine-item measure and strong internal consistency, test-retest reliability, and good convergent/divergent validity was demonstrated with an independent sample. When administered to a replication sample, indexes suggested an excellent model fit. The Abbreviated Math Anxiety Scale (AMAS) may represent a more parsimonious and valid approach to assess mathematics anxiety.*

Keywords: math anxiety; assessment; factor analysis

Mathematics anxiety involves increased physiological reactivity (Dew, Galassi, & Galassi, 1984), negative cognitions (Ashcraft & Kirk, 2001), avoidance behavior, and substandard performance when presented with math stimuli (Ashcraft & Faust, 1994; Chipman, Krantz, & Silver, 1992). Pioneering work on the assessment of math anxiety involved construction of the 98-item Math Anxiety Rating Scale (MARS) (Richardson & Suinn, 1972), which was followed by the creation of several abbreviated instruments (Alexander & Martray, 1989; Fennema & Sherman, 1976; Plake & Parker, 1982; Sandman, 1979). With the exception of some data addressing the reliability and validity of the full-length MARS (Alexander & Cobb, 1989; Dew et al., 1984; Richardson & Suinn, 1972), the psychometric properties of the abbreviated measures generally have been understudied. Even within the defining articles, significant methodological limitations are evident, including small sample sizes and lack of test-retest data (Plake & Parker, 1982), as well as omission of measures to assess convergent and divergent validity (Alexander & Martray, 1989). Perhaps more disconcerting, prevailing conceptual models of math anxiety (i.e., factor structures of self-report measures) generally have been accepted without the empirical scrutiny necessary to establish the construct validity of these measures.

This practice may be detrimental to math anxiety research, as these models may be nonrepresentative of the emotional experience of math anxiety, which would threaten the internal and external validity of studies. This hypothesis is at least partially supported by a recent confirmatory factor-analytic study in which the two-factor structure of the Math Anxiety Rating Scale–Revised (MARS-R) (Plake & Parker, 1982) proved to be a remarkably poor fit to data obtained from a large sample of undergraduates (Hopko, in press). Given the current status of math anxiety assessment, this study was designed to (a) develop an abbreviated measure of math anxiety using a large representative sample; (b) evaluate the measure on an independent sample by assessing its factor structure, internal consistency, test-retest reliability, and convergent/divergent validity; and (c) assess the generalizability of the model across a third independent sample.

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Assessment, Volume 10, No. 2, June 2003 178-182
DOI: 10.1177/1073191103252351

METHOD

Participants

Participants included 1,239 undergraduate students (729 females, 510 males). The sample consisted of 1,130 Caucasians (91%), 60 African Americans (5%), 24 Hispanics (2%), 8 Asian Americans (1%), 2 Native Americans (0.1%), and 15 individuals (1%) who categorized themselves as "other." The mean age of participants was 19.6 years (*SD* = 3.0 years).

Assessment Measures

The MARS-R (Plake & Parker, 1982) is a 24-item version of the MARS (Richardson & Suinn, 1972). The MARS-R measures anxiety in math-related situations, has a coefficient alpha of .98, and correlates .97 with the MARS (Plake & Parker, 1982).

The State-Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) is a 40-item scale used to measure state and trait anxiety. Good to excellent internal consistency (α = .86-.95) and adequate test-retest reliability (State: *r* = .71-.76; Trait: *r* = .75-.86) has been reported (Spielberger et al., 1983).

The Test Anxiety Inventory (TAI) (Spielberger, 1977) measures anxiety in test-taking situations. Reliability coefficients (α) range from .93 to .96, and convergent validity with other measures of test anxiety is strong (Sarason, 1978).

The Beck Anxiety Inventory (Beck & Steer, 1993) is a 21-item measure of cognitive and somatic symptoms of anxiety with excellent internal consistency (α = .85-.92) and adequate test-retest reliability (*r* = .75) (Beck, Epstein, Brown, & Steer, 1988; Beck & Steer, 1993).

The Fear of Negative Evaluation Scale (FNE) (Watson & Friend, 1969) assesses expectations of negative evaluation and has high internal consistency (α = .94-.96), strong test-retest reliability (*r* = .78-.94), and good criterion validity (Watson & Friend, 1969).

The 20-item Computer Anxiety Rating Scale (CARS) (Heinssen, Glass, & Knight, 1987) measures anxiety associated with computer tasks. The CARS has high internal consistency (α = .87), good test-retest reliability (*r* = .70), and good discriminant validity (Heinssen et al., 1987).

Procedure and Data Analyses

The developmental sample completed the MARS-R (*n* = 815) after which an exploratory factor analysis was conducted using a principal components extraction and varimax rotation within a two-factor forced solution. The factor loadings, interpretability (i.e., face validity of items), and scree-plot analysis were used to create the Abbreviated Math Anxiety Scale (AMAS). The primary (testing) sample (*n* = 206) then completed the AMAS as part of a comprehensive assessment battery. An exploratory analysis was conducted on the AMAS again using principal components extraction with varimax rotation. Test-retest of the AMAS occurred at an interval of 2 weeks from the administration of the assessment battery. In the final stage, an independent replication sample (*n* = 218) completed the AMAS. A confirmatory factor analysis was conducted to determine the adequacy of the factor structure established during the previous stage. Fit indexes were derived using Statistical Analysis System (SAS) CALIS (Hatcher, 1994). As per recommendations in reporting results of confirmatory procedures (Thompson & Daniel, 1996), the root mean square error of approximation (RMSEA), chi-square, and the Bentler's comparative (BCFI), goodness-of-fit (GFI), and adjusted goodness-of-fit (AGFI) indexes are presented. Contemporary goodness-of-fit criteria were used whereby an RMSEA of .06 and a CFI (and GFI) value of .95 are required before conclusions can be drawn that there is a good fit between the hypothesized model and the observed data (Hu & Bentler, 1998).

RESULTS

Development Sample

Exploratory factor analysis. Prior to conducting the analysis, data were subjected to tests of multivariate normality (Hair, Anderson, Tatham, & Black, 1995). Both the symmetry (skewnesss = .32, *SE* = .09) and the "flatness" (kurtosis = –.31, *SE* = .17) of the distribution were within acceptable limits (Hair et al., 1995), and the Shapiro-Wilk statistic suggested the sample data were drawn from a normally distribution (*W* = .98, *ns*).

The two-factor exploratory analysis accounted for 52% of the variance. Factor loadings ranged from .42 to .73 on the Learning Math Anxiety (LMA) factor and from .26 to .88 on the Math Evaluation Anxiety (MEA) factor. In developing a briefer and more parsimonious measure of math anxiety, salient factor loadings included structure coefficients that exceeded .70 on one of the two factors. This value was chosen based on a scree plot analysis of factor loadings that indicated a straightening of the slope with values less than .70. Accordingly, 10 items initially were retained on the AMAS. Because of perceived redundancy of two items (Items 10 and 21), these items were combined into "taking an examination in a math course." The end result was a 9-item AMAS.

Primary (Testing) Sample

Exploratory factor analysis. An exploratory factor analysis was conducted on the 9-item AMAS. Items on the AMAS were responded to using a 5-point Likert-type scale, ranging from 1 (*low anxiety*) to 5 (*high anxiety*), with the total score representing a summation of the nine items. The optimal factor solution was determined using Cattell's "scree" test (Cattell, 1966), factor interpretability, and factor eigenvalues (Hair et al., 1995). A two-factor solution was identified that accounted for 70% of the variance. The factors were best interpreted using the initial subscale designations of LMA and MEA. AMAS items and their factor loadings are presented in Table 1.

Descriptive data. For the primary (testing) sample, self-reported math anxiety on the AMAS was as follows: $M = 21.1$, $SD = 7.0$. Consistent with previous literature (Hembree, 1990), a gender effect was identified whereby female students ($M = 21.9$, $SD = 6.9$) reported more math anxiety than male students ($M = 19.5$, $SD = 6.9$), $t(204) = 2.25$, $p < .05$. Self-reported math anxiety also was moderately related to the number of high school math courses taken ($r = –.31$, $p < .001$) and grades earned in these courses ($r = –.52$, $p < .001$). When individuals were categorized on the basis of ethnicity (i.e., Caucasian/non-Caucasian) there was no difference as a function of mathematics anxiety, $t(205) = .52$, $p = .61$. Self-reported math anxiety correlated weakly with age ($r = .08$).

Internal consistency. Internal consistency was excellent within the AMAS ($\alpha = .90$), as well as the LMA ($\alpha = .85$) and MEA subscales ($\alpha = .88$).

Test-retest reliability. Two-week test-retest reliability was excellent on the AMAS ($r = .85$) as well as the LMA ($r = .78$) and MEA subscales ($r = .83$).

Convergent and divergent validity. Bivariate correlations were calculated between the AMAS and other anxiety measures (Table 2). The MEA and LMA subscale scores correlated strongly with one another ($r = .62$), and each was strongly related to the total score (LMA: $r = .88$, MEA $r = .92$). Strong convergent validity was evident between the original MARS-R and the AMAS ($r = .85$), AMASlma ($r = .70$), and the AMASmea ($r = .81$). In general, moderate associations were obtained among the AMAS total and subscale scores, with other anxiety measures ($r = .20$-$.54$) indicating some level of divergent validity with these measures. Statistical comparisons of dependent *r*s (Cohen & Cohen, 1983) indicated no significant correlative differences between the AMAS and the MARS-R (for correlations, see Hopko, in press) as they related to alternate anxiety measures.

TABLE 1
Factor Loadings of Retained AMAS Items

Item	Factor Loading: Learning Math Anxiety	Factor Loading: Math Evaluation Anxiety
1. Having to use the tables in the back of a math book.	*.52*	.35
2. Thinking about an upcoming math test 1 day before.	.27	*.86*
3. Watching a teacher work an algebraic equation on the blackboard.	*.77*	.35
4. Taking an examination in a math course.	.22	*.89*
5. Being given a homework assignment of many difficult problems that is due the next class meeting.	.31	*.66*
6. Listening to a lecture in math class.	*.86*	.25
7. Listening to another student explain a math formula.	*.82*	.17
8. Being given a "pop" quiz in math class.	.29	*.84*
9. Starting a new chapter in a math book.	*.75*	.26

NOTE: AMAS = Abbreviated Math Anxiety Scale. Factor loadings in italics specify the designated factor.

Replication Sample

Descriptive data and internal consistency. For the replication sample, self-reported math anxiety on the AMAS was as follows: $M = 23.2$, $SD = 5.8$. Consistent with the primary sample, a gender effect was identified whereby female students ($M = 23.8$, $SD = 5.7$) reported more mathematics anxiety than male students ($M = 21.5$, $SD = 5.7$), $t(217) = 2.40$, $p < .05$. Again, self-reported math anxiety was moderately related to the number of high school math courses taken ($r = –.15$, $p < .05$) and the grades earned in these courses ($r = –.34$, $p < .01$). Similar to the primary sample, there was no difference in self-reported mathematics anxiety as a function of ethnicity, $t(217) = .85$, $p = .40$, and math anxiety was weakly correlated with age ($r = .03$). Internal consistency was adequate within the AMAS ($\alpha = .83$) as well as the LMA ($\alpha = .74$) and MEA subscales ($\alpha = .81$).

Confirmatory factor analysis. A confirmatory factor analysis was conducted on the replication sample to assess the validity of the nine-item model. The two-factor model had goodness-of-fit indexes as follows: $\chi^2 = 50.81$ (26 *df*), RMSEA = .06, GFI = .95, AGFI = .92, BCFI = .96. Standardized path coefficients for the revised model ranged from .43 (Item 1: LMA) to .86 (Item 2: MEA). Separate

TABLE 2
Correlations Among Self-Report Assessment Instruments

Instrument	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1. AMAS	—	.88**	.92**	.85**	.52**	.33**	.26**	.28**	.32**	.32**
2. AMASlma		—	.62**	.70**	.38**	.22**	.20**	.21**	.32**	.27**
3. AMASmea			—	.81**	.54**	.37**	.26**	.28**	.26**	.30**
4. MARS-R				—	.54**	.37**	.28**	.26**	.25**	.40**
5. TAI					—	.51**	.29**	.43**	.33**	.25**
6. BAI						—	.43**	.60**	.19**	.26**
7. STATE							—	.66**	.31**	.26**
8. TRAIT								—	.45**	.26**
9. FNE									—	.12
10. CARS										—

NOTE: AMAS = Abbreviated Math Anxiety Scale; AMASlma = Abbreviated Math Anxiety Scale–Learning Math Anxiety subscale; AMASmea = Abbreviated Math Anxiety Scale–Math Evaluation Anxiety subscale; MARS-R = Mathematics Anxiety Rating Scale–Revised; TAI = Test Anxiety Inventory; BAI = Beck Anxiety Inventory; STATE = State-Trait Anxiety Inventory–State; TRAIT = State-Trait Anxiety Inventory–Trait; FNE = Fear of Negative Evaluation Scale; CARS = Computer Anxiety Rating Scale.

confirmatory factor analyses were conducted to examine model fit as a function of gender. Goodness-of-fit indexes were excellent for both female students, $\chi^2 = 37.56$ (26 *df*), RMSEA = .05, GFI = .95, AGFI = .91, BCFI = .97, and male students, $\chi^2 = 36.98$ (26 *df*), RMSEA = .07, GFI = .93, AGFI = .90, BCFI = .93.

DISCUSSION

Using a large sample size, this study was designed to develop and establish the psychometric properties of the AMAS among university undergraduates. Having created the 9-item AMAS with a development sample, the reliability and validity of this measure were tested using a second independent sample. Internal consistency and test-retest reliability of the measure were strong. Convergent validity was evident in the strong association between the AMAS and the MARS-R, as well as replication of the finding that math anxiety is more pervasive among female students (Hembree, 1990). Divergent validity also was apparent between the AMAS and other commonly administered measures of acute, chronic, and performance anxiety. Confirmatory factor analyses on a third (replication) sample provided strong support for the 9-item abbreviated measure, with the attainment of excellent goodness-of-fit values using multiple indexes. As such, these data support the notion that the abbreviated measure may be an externally valid, more parsimonious, and superior measure of math anxiety as compared with the original instrument (MARS-R).

Given the methodological limitations and paucity of psychometric research associated with previously established abbreviated measures, the present findings are promising as we seek to better assess and treat individuals who exhibit problems with mathematics anxiety. The finding that gender differences continue to be evident on self-report measures of math anxiety is concerning. Whether this finding represents an actual gender difference or is more a function of increased willingness of female students to endorse anxiety symptoms, data suggest that female students are more apt to avoid mathematics courses and careers that require math skills (Chipman et al., 1992). This needless limitation of educational and occupational opportunities subsequently may reduce the nation's resources in areas such as accounting, engineering, and other math-related fields. A more concentrated effort must therefore be made toward modifying social learning such that female students may be less inclined to perceive mathematics as male dominated and more inclined to pursue courses and careers in these areas. This process may be facilitated by early assessment of math attitudes and anxiety of which the AMAS may serve a useful purpose.

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