

Measuring Mathematics Anxiety: Psychometric Analysis of a Bidimensional Affective Scale

Haiyan Bai, LihShing Wang, Wei Pan, and Mary Frey

The purpose of this study is to develop a theoretically and methodologically sound bidimensional affective scale measuring mathematics anxiety with high psychometric quality. The psychometric properties of a 14-item Mathematics Anxiety Scale-Revised (MAS-R) adapted from Betz's (1978) 10-item Mathematics Anxiety Scale were empirically analyzed on a college sample for its internal consistency reliability, parallel-item reliability, and construct validity. In addition, the bidimensionality of MAS-R was verified through the two-factor measurement model that fitted to the data significantly better than the one-factor model. Therefore, MAS-R is a psychometrically reliable and valid instrument for measuring bidimensional mathematics anxiety. Implications of the bidimensional affective scale in measuring mathematics anxiety are discussed.

Keywords: mathematics anxiety, Mathematics Anxiety Scale, mathematics education, psychometric property, factor analysis

Mathematics education has been in the center stage of accountability reform since the *No Child Left Behind Act* went into effect in 2002 (NCLB, 2002). Mathematics literacy is regarded as a "civil issue" because of its leverage in mitigating social and economic inequity (Schoenfeld, 2002). Students and educators alike are under unprecedented pressure to achieve state proficiency standards and to close the achievement gaps (Farmer, 2005; Harris & Herrington, 2006; Jones, Jones, & Hargrove, 2003; Taylar, 2006; YeopKim, Zabel, Stiefel, & Schwartz, 2006). Among the many correlates of mathematics achievement, mathematics anxiety has been shown to be a significant factor of learning success (Cates & Rhymer, 2003; Hembree, 1990; Pajares & Miller, 1994; Ramirez & Dockweiler, 1987; Ryan & Ryan, 2005; Singh, Granville, & Dika, 2002). Individuals with high mathematics anxiety tend to perform poorly when presented with mathematics

stimuli (Cates & Rhymer, 2003) with a common population correlation estimated at $-.27$ (Ma, 1999). Furthermore, individuals with mathematics anxiety have shown to avoid environments and careers that require the utilization of mathematics skills (Ashcraft, 2002). Therefore, it can be inferred that mathematics anxiety greatly impacts mathematics education and students' career choice.

Research on mathematics anxiety has shown that it is a multidimensional psychological construct that involves complex factors, such as feelings of pressure, performance inadequacy, and test anxiety that interfere with the manipulation of numbers and solving mathematical problems in a wide variety of ordinary life and academic situations (Kazelskis, 1998; McMorris, 2004; Rounds & Hendel, 1980). The measurement of mathematics anxiety is important for understanding the nature of this construct and the degree of its presence for intervention planning and instructional delivery (Hembree, 1990; McMorris, 2004; Newstead, 1998).

Over the past three decades, researchers have focused on developing self-report instruments to measure mathematics anxiety. A pioneering work on measuring mathemat-

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ics anxiety was the Mathematics Anxiety Rating Scale (MARS) (Richardson & Suinn, 1972), a 98-item instrument with a 5-point Likert scale designed to measure college students' mathematics anxiety. MARS was once regarded as the best available measure of mathematics anxiety with the highest reliability and validity (Dew, Galassi, & Galassi, 1983; Hopko, Mahadevan, Bare, & Hunt, 2003; Richardson & Woolfolk, 1980); however, the 98-item instrument was cumbersome to administer (Pajares & Urdan, 1996), and it has been out of print since 1994.

Following the publication of MARS, several revisions were developed. For example, the Mathematics Anxiety Rating Scale for Adolescents (MARS-A) (Suinn & Edwards, 1982) and the Mathematics Anxiety Rating Scale for Elementary School Students (MARS-E) (Suinn, Taylor, & Edwards, 1988) were developed. MARS-A consists of 98 questions with a 5-point Likert scale. The Cronbach's alphas, i.e., internal consistency reliability coefficients, ranged from .89 to .96, but no validity information was clearly reported (McMorris, 2004). MARS-E has 26 items with a 5-point Likert scale, and its Cronbach's alpha was .88. The two primary factors, mathematics test anxiety and mathematics performance adequacy anxiety of MARS-E, however, accounted for less than 30% of the variance (McMorris, 2004). In his review of MARS, MARS-A, and MARS-E, McMorris (2004) suggested that additional or revised measures need to be developed to improve the measurement of mathematics anxiety.

To reduce the test length, Plake & Parker (1982) modified MARS and developed the Math Anxiety Rating Scale-Revised (MARS-R), a shorter, 24-item version of the 98-item MARS. Although it yielded a high reliability estimate of .98, MARS-R was demonstrated to be a remarkably poor fit to a large sample of undergraduates (Hopko, 2003). The latest measure of mathematics anxiety is Hopko et al.'s (2003) Abbreviated Math Anxiety Scale

(AMAS), an adapted version of MARS-R with only nine items. AMAS was reported to have two factors, learning mathematics anxiety and mathematics evaluation anxiety, which accounted for 70% of the variance from an exploratory factor analysis using principal components extraction with varimax rotation. However, some factor loadings were found to be non-significant, and the varimax rotation is dubious because its orthogonality assumes no correlation between the factors, which runs counter to the concept that the two factors should be related with each other.

Another line of research independent of the MARS family was initiated by Fennema and Sherman (1976). They developed the Mathematics Attitudes Scale, a 12-item, 5-point Likert-scale instrument used for high school students. This brief scale was intended to assess the feelings of anxiety, dread, and nervousness associated with mathematics. However, there was little research about the validity and reliability of the scale, which seriously hindered its use for research purposes (Rounds & Hendel, 1980). Later, Sandman (1980) designed the Mathematics Attitude Inventory (MAI) to measure attitudes toward mathematics of secondary-school students with 48 items. MAI reported six subscales measuring the following constructs: (a) perception of the mathematics teacher, (b) anxiety toward mathematics, (c) value of mathematics in society, (d) self-concept in mathematics, (e) enjoyment of mathematics, and (f) motivation in mathematics. The Cronbach alphas for the six subscales ranged from .68 to .89, but no validity data were reported.

With the exception of MAI, the abovementioned mathematics anxiety measures were all developed with unidimensional representation of negative affect consistent with anxiety. However, Kazelskis (1998) identified positive affect toward mathematics as one of the six oblique factors in mathematics anxiety: mathematics test anxiety, numerical anxiety, negative affect

toward mathematics, worry, positive affect toward mathematics, and mathematics course anxiety. Watson (1988) pointed out that positive affect reflected a degree of pleasurable interaction with the environment, whereas negative affect reflected an adverse response to the environment. The items of negative affect toward mathematics indicate feelings of discomfort, restlessness, uneasiness, and confusion; while the items of positive affect toward mathematics indicate a sense of ease, a lack of discomfort, and the absence of fear (Kazelskis, 1998). To better understand the construct of mathematics anxiety so as to find better intervention strategies to reduce anxiety, the inclusion of the positive affect of mathematics anxiety would be helpful.

Betz (1978) intended to measure mathematics anxiety from both positive and negative affects and created the Mathematics Anxiety Scale (MAS) by adapting Fennema and Sherman's (1976) Mathematic Attitudes Scale. MAS is a 10-item scale with five items positively worded and the other five items negatively worded. Pajares and Urdan (1996) pointed out that the MAS has acceptable stability and internal consistency. MAS was reported to have a Cronbach's alpha of .72 and test-retest reliability of .87 for undergraduates (Dew, Galassi, & Galassi, 1983). However, when examining the two-factor structure of MAS, Pajares and Urdan (1996) found that Item 6 did not load on either of the two factors, positive affect and negative affect; and Item 1 failed to load or loaded weakly across different samples, such as middle school, high school, and college. Therefore, MAS has some construct validity problems.

The above review of the existing mathematics anxiety instruments clearly calls for a bidimensional measure that would capture both positive and negative affects of the latent construct of mathematics anxiety. In addition, for an instrument to have adequate measurement efficiency, its test length must be optimized with desirable psychometric quality. Therefore, the purpose of the

present study is to develop a theoretically and methodologically sound bidimensional instrument of mathematics anxiety with high psychometric quality. Specifically, the psychometric properties under investigation include (a) internal consistency reliability, (b) parallel-item consistency, (c) item-total correlation, (d) factor structure, and (e) measurement model fit to the sample data. The first three objectives address test reliability and the latter two objectives address test validity.

Method

Participants

A sample of 78 undergraduate students, intact groups of students from different disciplines, enrolled in entry-level mathematics courses from a Midwest community college voluntarily participated in the study. The sample consisted of 36 males and 42 females, with 64% of the sample between ages of 18 and 24 and 36% of the sample over the age of 25. The research protocol was approved by the Institutional Review Board at one of the authors' institutions. The researchers took special care to avoid coercion because the researcher who collected the data was also a faculty member at the research site.

Instrument Development

The instrument selected for adaptation was MAS (Betz, 1978), consisting of ten items on a five-point Likert scale. Questions included in MAS were intended to identify the bidimensional affects, positive and negative, toward mathematics. In MAS, the first five items were positively worded and the last five items negatively worded. Positively worded items were reversed for scoring so that a high score indicates high anxiety (Pajares & Urdan, 1996).

Previous research has suggested that some MAS items (e.g., Items 1 and 6) need to be revised for wording (Pajares & Urdan, 1996). In the present study, the researchers developed the revised version of MAS (MAS-

R) by making the following improvements:

1. In MAS, several positive-affect items were negatively phrased (e.g., "It wouldn't bother me at all to take more math classes" and "I almost never get uptight while taking math tests"). In the present study, we revised those items so that the positive-affect items were also positively phrased (e.g., "I enjoy learning mathematics").
2. Some negative-affect items were double-barreled (Litwak, 1956) in MAS (e.g., "Mathematics makes me feel uncomfortable and nervous"). In MAS-R, the item was broken down into two items: "Mathematics makes me feel uncomfortable" and "Mathematics makes me feel nervous."
3. Some positive-affect items were added to measure the positive affect according to the positive affect theory (Kazelskis, 1998; Watson, 1988).
4. The MAS items were sorted by the direction of the phrasing, i.e., all positives and then all negatives. We randomly ordered the positive- and negative-affect items in MAS-R so that the psychometric construct was measured more accurately by avoiding the emotional reactions to an assessment situation for both students with high mathematics anxiety and those with low mathematics anxiety (Carp, 1974; Krosnick & Alwin, 2001; Nitko & Brookhart, 2007).
5. Item 1 in MAS had non-significant loadings on all factors in the college sample. Also, Item 6 was found to use an intensity modifier "really" that could skew the response (Pajares & Urdan, 1996). In the present study, we deleted Item 1 and changed "really uptight" to "uptight" for Item 6.
6. A parallel item was added with identical wording for the purpose of checking parallel-item reliability. The item was taken out from the final version of MAS-R.

Format. The first version of the instrument is a 14-item paper-and-pencil questionnaire, plus the duplicated parallel item. The typical timeframe for completion is approximately 10 minutes. The response categories are on a five-point Likert-scale. These polytomous response choices were scored as 1 = *Strongly Disagree*, 2 = *Disagree*, 3 = *Neutral*, 4 = *Agree*, and 5 = *Strongly Agree* for negative items, and the positive-affect items were reversed for scoring so that a high score indicates high anxiety.

Procedure. A standardized procedure was employed in administering the instrument to different classes, including uniform paper copies of the instrument and written instructions to be read as directions prior to administration. The same researcher administered the questionnaire to all the participants by following the standardized procedure.

Data Analysis

Internal consistency reliability, parallel-item consistency, item-total correlation, and factor structure were analyzed by using the Statistical Package for the Social Sciences (SPSS) (SPSS Inc., 2006). An exploratory factor analysis was conducted to identify factor structure using a principal axis factoring extraction method, and the final factor solution was estimated by using principal components. The Kaiser-Meyer-Olkin measure of sample adequacy was .87, greater than the minimally accepted level of .50, indicating that the sample was adequate for the factor analysis (Kaiser & Rice, 1974). To justify the bidimensionality of MAS-R, the chi-square model-fit indices for the one-factor measurement model and the two-factor measurement model were compared using the Analysis of Moment Structures (AMOS) (Arbuckle, 2006).

Results

Test Reliability

Internal consistency reliability. The Cronbach's alpha coefficient assessing the

internal consistency of the instrument for the total scale was found to be .91. This result is much better than the .72 reported by Dew, Galassi, and Galassi (1983) and also better than the .86 to .90 reported by Hackett and Betz (1989) for the original MAS. This high internal consistency of MAS-R suggests that the 14 items, even though they were bidimensionally-scaled, turned out to be an internally consistent measure of the mathematics anxiety construct.

Parallel-item consistency. The two identical items, Items 9 and 15, used for checking response consistency, were found to have a correlation of .87. This parallel-item reliability indicates a reasonable consistency response pattern.

Item-total correlation. Pearson's correlation between each item and the total scale is reported in Table 1. In addition, the Cronbach's alpha coefficient of the total scale after each item deleted is also reported. The large, positive item-total correlations indicate that all items measure consistently

with the total scale, suggesting a strong item discrimination power. However, two items had relatively low item-total correlations, such as Item 3, "I think that I will use math in the future" ($r = .31$) and Item 5, "Math relates to my life" ($r = .26$). It is of interest to note that overall the positive-affect items tend to have lower item-total correlations (from .26 to .74, with a median of .51) than the negative-affect items (from .57 to .75, with a median of .67). Nonetheless, we would recommend keeping them in the instrument because they together with other positive items do measure well the positive dimension of mathematics anxiety.

Test Validity

Factor structure (Construct validity). Using a set of criteria, e.g., eigenvalue (> 1.00), scree plot, and variance explained ($> 60\%$), the exploratory factor analysis identified two factors (see Table 2). The two factors explained 66.7% of the total variance of the 14 items. The factor loadings ranged

Table 1
Item-Total Correlation and Internal Consistency Reliability of MAS-R

Item	Affect Dimensionality	Correlation with Total	Cronbach's Alpha ^a
1. I find math interesting.	Positive	.59	.90
2. I get uptight during math tests.	Negative	.68	.90
3. I think that I will use math in the future.	Positive	.31	.91
4. Mind goes blank and I am unable to think clearly when doing my math test.	Negative	.63	.90
5. Math relates to my life.	Positive	.26	.91
6. I worry about my ability to solve math problems.	Negative	.66	.90
7. I get a sinking feeling when I try to do math problems.	Negative	.63	.90
8. I find math challenging.	Negative	.57	.90
9. Mathematics makes me feel nervous.	Negative	.73	.90
10. I would like to take more math classes.	Positive	.54	.90
11. Mathematics makes me feel uneasy.	Negative	.74	.89
12. Math is one of my favorite subjects.	Positive	.74	.89
13. I enjoy learning with mathematics.	Positive	.64	.90
14. Mathematics makes me feel confused.	Negative	.75	.89

^aThe Cronbach's alpha coefficient indicates the internal consistency reliability of the total scale if the item is deleted.

from .67 to .89 for the negative-affect factor and from .67 to .87 for the positive-affect factor. The substantial amount of variance explained and the significantly large loadings suggest that the 14-item bidimensional scale, MAS-R, is a valid instrument to measure mathematics anxiety with both positive and negative affects.

Measurement model fit. Two measurement models were conducted, one with one factor including all the 14 items and the other with two factors identified from the positive and negative theory (Kazelskis, 1998; Watson, 1988) and the explanatory factor analysis. The chi-square was $\chi^2 = 330.01$, $df = 77$, for the one-factor model and $\chi^2 = 164.54$, $df = 76$, for the two-factor model. The difference between the two chi-square model-fit indices was significant ($\Delta\chi^2 = 165.47$, $\Delta df = 1$, $p < .001$), which indicates that the two-factor model fitted to the data significantly better than the one-factor model. Therefore, the two-factor

measurement model has excellent construct validity in representing mathematics anxiety on a bidimensional scale.

Discussion

The revised 14-item bidimensional Mathematics Anxiety Scale (MAS-R) was found to have high internal consistency reliability, parallel-item consistency, and construct validity. The fact that the two-factor solution was significantly better than the one-factor solution indicates that the bidimensional scale optimally captured the two dimensions of mathematics anxiety. In other words, both high-anxiety and low-anxiety students can respond well to this bidimensional scale so that their relative positions on positive and negative affects can be accurately located. This bidimensional finding overturns the earlier belief that the positive and negative affects are bidirectional manifestations of the same dimension (Scheier & Carver, 1985) but supports the later finding that they

Table 2
Exploratory Factor Structure of MAS-R using Principal Components Analysis

Items	Factor 1 (Negative)	Factor 2 (Positive)
11. Mathematics makes me feel uneasy.	.89	.12
9. Mathematics makes me feel nervous.	.89	.09
6. I worry about my ability to solve math problems.	.83	.07
2. I get uptight during math tests.	.83	.08
7. I get a sinking feeling when I try to do math problems.	.79	.08
4. Mind goes blank and I am unable to think clearly when doing my math test.	.78	.08
14. Mathematics makes me feel confused.	.74	.34
8. I find math challenging.	.67	.13
1. I find math interesting.	.21	.87
3. I think that I will use math in the future.	-.11	.82
13. I enjoy learning with mathematics.	.30	.80
10. I would like to take more math classes.	.24	.73
5. Math relates to my life.	-.08	.69
12. Math is one of my favorite subjects.	.51	.67
Variance Explained	46.5%	20.2%

are two correlated but different dimensions (Marshall, Wortman, Kusuals, Herving, & Vickers, 1992). Therefore, the results of this study strongly support the argument that mathematics anxiety can be measured on a bidimensional scale with positive- and negative-affect items which will be more accurate to measure the mathematics anxiety over a sample of students with negative or positive affect.

Future research may replicate this study on a larger scale with a more diverse sample at varied settings. With its reading level estimated at Grade 4 by the Flesch-Kincaid readability scale (Kincaid, Fishburne, Rogers, & Chissom, 1975), it would be of interest, for example, to test the reliability and validity of MAS-R with a secondary-school or even elementary-school population. Another line of future research may examine the causal relationship between mathematics anxiety and mathematics performance. For example, it would be of interest to design intervention programs aiming at reducing mathematics anxiety and to investigate its effect on mathematics learning. Given the bidimensionality of the scale, it is important to note that interventions designed to reduce negative affect may not increase positive affect (Pretzer & Walsh, 2003). Further investigation is also needed to replicate the bidimensionality of the scale across different subject matters and various demographic groups.

This study is expected to make an important contribution to mathematics education research and practice. The intellectual merit of developing a theoretically and methodologically sound bidimensional instrument of mathematics anxiety suggests that this instrument can serve as a research tool for investigating the nomological framework of the latent construct, in addition to addressing how the construct under the investigation relates to other phenomena of interest. The practical merit of this study is that the instrument includes the ability for classroom teachers

and school counselors to quickly administer the instrument, assess the nature, origins, and severity of mathematics anxiety and to develop intervention strategies to mitigate its negative consequences. The broader impact of this study aims to interrupt the vicious cycle concerning the interaction of mathematics anxiety with cognitive processing in an effort to ultimately improve mathematics learning.

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