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PSYCHOMETRIC PROPERTIES OF THE REVISED MATHEMATICS ANXIETY RATING SCALE

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An exploratory factor analysis and several confirmatory analyses were performed to evaluate the factorial structure of the Revised Mathematics Anxiety Rating Scale (RMARS) through the responses of 805 college students. On 559 students' scores, the instrument's construct validity was tested through a confirmatory factor analysis (CFA) and was found to be inadequate. An exploratory factor analysis suggested a modification by dropping five items. After the modification, a second CFA showed that the modified model fit the theoretical model well. Cross-validation of the modified model was tested on a different sample of 246 students and was found to be satisfactory. In addition, concurrent validity of the instrument was found from significant relationships between the modified RMARS scores and students' self-perceptions of their general and current mathematics anxiety levels. The modified RMARS is valid and reliable and could be used as a screening tool, a placement tool, or a research tool.

Interest in mathematics anxiety started with the observations of mathematics teachers in the early 1950s. In 1957, Dreger and Aiken introduced *mathematics anxiety* as a new term to describe students' attitudinal difficulties with mathematics. They defined it as "the presence of a syndrome of emotional reactions to arithmetic and mathematics" (p. 344).

Notwithstanding the difficulties in defining and measuring mathematics anxiety (Wood, 1988), several attempts have been made to assess it. Atkinson (1988) described three distinct periods in the measurement of mathematics anxiety. In the first period, most studies were merely the authors' opinions and did not employ any standardized mathematics anxiety measures. During this period, an awareness of anxiety about mathematics arose and mathematics anxiety was being defined (e.g., Gough, 1954).

The authors express their gratitude to two anonymous reviewers, whose comments and suggestions led to a more comprehensive paper. Special thanks to Philip Brady, Ph.D., for allowing us to use a data set (Bowd & Brady, 2002). Address correspondence to Mustafa Baloğlu, Ph.D., Gaziosmanpasa University, College of Education, Department of Educational Sciences, Tokat 60110 Turkey. (E-mail: baloglu@hotmail.com).

Next, studies focused on the assessment of attitudes toward mathematics through surveys that included several variables such as state-trait anxiety, confidence, enjoyment, and misconceptions (e.g., Dutton & Blum, 1968). The third period saw the development of standardized mathematics anxiety instruments. Dreger and Aiken developed the first instrument, the Number Anxiety Scale, in 1957. Afterwards, more comprehensive scales such as the Mathematics Anxiety Rating Scale (Richardson & Suinn, 1972), the Fennema-Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976), the Anxiety Towards Mathematics Scale (Sandman, 1980), and the Mathematics Anxiety Questionnaire (Wigfield & Meece, 1988) were developed.

Even though the Mathematics Anxiety Rating Scale (MARS; Richardson & Suinn, 1972) is one of the most extensively used mathematics anxiety instruments, Alexander and Martray (1989) reported two major shortcomings. The first is that it is a long assessment instrument (98 items), time-consuming to administer and to score. However, the Revised Mathematics Anxiety Rating Scale (RMARS; Alexander & Martray), developed from the original MARS, has only 25 items.

In a more recent attempt to develop an abbreviated version of the MARS, Suinn and Winston (2003) investigated the previous studies that attempted to shorten the original MARS (e.g., Levitt & Hutton, 1984; Rounds & Hendel, 1980; Plake & Parker, 1982; Alexander & Martray, 1989) and generated 30 items from Alexander and Cobb (1984), Alexander and Martray, and Rounds and Hendel. The rules Suinn and Winston used for inclusion were that an item should (a) be found as an important factor in at least two of the studies or (b) show the highest loading among factors in at least one of the studies. The 30 collected items were subjected to a principal components analysis with oblique rotation, and two factors that emerged accounted for 70.3% of the total variability in the MARS items. Mathematics Test Anxiety accounted for 59.2% of the variance, whereas Numerical Anxiety accounted for 11.1% of the variance.

Extensive research has been done on the MARS and its psychometric properties (e.g., Camp, 1992; Capraro, Capraro, & Henson, 2002; Dew, Galassi, & Galassi, 1984; Resnick, Viehe, & Segal, 1982; Richardson & Suinn, 1972; Rounds & Hendel, 1980; Strawderman, 1985; Suinn & Edwards, 1982). However, the second, and more important, shortcoming of the instrument is that the proposed underlying construct of the MARS is unidimensional (Richardson & Suinn, 1972; Suinn, Edie, Nicoletti, & Spinelli, 1972). Nonetheless, more recent studies have revealed that there may be more than one underlying construct in mathematics anxiety (e.g., Alexander & Cobb, 1984; Alexander & Martray, 1989; Brush, 1981; Ferguson, 1986; Plake & Parker, 1982; Resnick et al., 1982; Rounds & Hendel, 1980; Satake & Amato, 1995).

Ling (1982) investigated the validity of mathematics anxiety as a multidimensional construct and found six factors (i.e., Personal Effectiveness; Assertiveness; Math Anxiety; Outgoingness; Success; and Dogmatism) that accounted for 76% of the total variance. Bessant (1995)

revealed that 43% of the variance in the MARS scores was explained by six factors: General Evaluation Anxiety, Everyday Numerical Anxiety, Passive Observation Anxiety, Performance Anxiety, Mathematics Test Anxiety, and Problem-Solving Anxiety. Kazelskis (1998) investigated the factor structure of the three most widely used mathematics anxiety scales: the RMARS (Alexander & Martray, 1989), the Mathematics Anxiety Questionnaire (MAQ; Wigfield & Meece, 1988), and the Mathematics Anxiety Scale (MAS; Fennema & Sherman, 1976). When an exploratory factor analysis, with a principal-axis component analysis and oblique rotation, was applied, the results revealed six dimensions of mathematics anxiety, which accounted for approximately 61% of the total variance. These six dimensions were Mathematics Test Anxiety, Numerical Anxiety, Mathematics Course Anxiety, Worry, Positive Affect Toward Mathematics, and Negative Affect Toward Mathematics. Kazelskis also pointed out that because "Numerical Anxiety appears to be distinct from the other dimensions . . . it could be argued that anxiety as a result of the manipulation of numbers is the sine qua non of mathematics anxiety" (p. 631).

The RMARS, on the other hand, is a mathematics anxiety instrument that assumes the multidimensionality of the construct. There are three subscales of the RMARS to measure the amount of mathematics anxiety that students usually experience. The Mathematics Test Anxiety subscale assesses student reactions to evaluative situations in mathematics. The Mathematics Course Anxiety subscale is designed to measure student reactions to being in a mathematics class. The Numerical Task Anxiety subscale measures anxiety due to basic math activities such as multiplication and division.

Psychometric properties of the RMARS were investigated in a few studies. Initial construct validity of the instrument was obtained from a sample of 517 undergraduate students (Alexander & Martray, 1989). A principal component factor analysis with squared multiple correlations as initial communality estimates and with a varimax rotation of the 69-item-version MARS revealed three factors, Mathematics Test Anxiety, Mathematics Course Anxiety, and Numerical Test Anxiety, which accounted for 31% of the variance in the RMARS scores. In a more recent study, Bowd and Brady (2002) conducted principal components analysis followed by varimax rotation on the results of 357 senior undergraduates in education and found three factors that accounted for 73% of the variability in the RMARS scores. The three factors were named Mathematics Test Anxiety (11 items), Mathematics Course Anxiety (8 items), and Numerical Task Anxiety (4 items).

Initial concurrent validity of the instrument was tested by comparing it with the Fennema-Sherman Attitude Scale (1976), and negative relationships were found, which meant that students who had more favorable attitudes toward mathematics experienced less mathematics anxiety (Alexander & Martray, 1989). In addition, Moore, Alexander, Redfield, and Martray (1988) found high to moderate correlations between the RMARS and the MAS (Fennema & Sherman, 1976), the State-Trait

Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), and the Test Anxiety Inventory (Spielberger, 1980). Alexander and Martray (1989) also found that the RMARS discriminated between students who took geometry or algebra in high school and students who did not. Students who took an algebra course ($F = 18.07$, $p < .001$) and a geometry course ($F = 25.60$, $p < .001$) in high school experienced significantly less mathematics anxiety compared with students who did not take these courses, as measured with the RMARS. Moore et al. (1988) also revealed that the RMARS scores were significantly correlated with the American College Testing mathematics scores and mathematics course grades. Moderate-to-high-reliability evidence was found for the total and subscales of the RMARS. Initial internal consistency reliability coefficients of the RMARS subscales were .96 for the Mathematics Test Anxiety, .86 for the Numerical Task Anxiety, and .84 for the Math Course Anxiety (Alexander & Martray, 1989).

Because the psychometric properties of the RMARS have not been fully investigated, we set out to investigate the validity and reliability of the scale. Validity was investigated in terms of its construct and concurrent validity. Individual RMARS items and three subscales were tested through a confirmatory factor analysis by means of structural equation modeling techniques. When the confirmatory factor analysis did not confirm the underlying factor structure of the RMARS, an exploratory factor analysis was used to discover which measured variables formed a common factor or factors. In addition, students' perceived general and current mathematics anxiety levels were used to investigate the concurrent validity of the RMARS. Perceived general mathematics anxiety levels were assessed on a scale of 0 to 100, where the higher ratings indicated the higher levels of mathematics anxiety that students usually experience. Similarly, perceived current mathematics anxiety levels were assessed on a scale of 0 to 100, where the higher ratings indicated the higher levels of mathematics anxiety that students were experiencing at the moment of administration. For the purpose of reliability, the consistency of the instrument's items was studied with internal consistency and split-half reliability coefficients.

Method

Two different samples were used in the present study (Sample 1 and Sample 2). Confirmatory and exploratory factor analyses were performed on Sample 1. The modified model was tested on both samples. Other analyses were done by using both samples.

Sample 1

Sample 1 consisted of college students who were attending classes in a large southwestern state university in the United States. Of the 559 students, 406 (72.6%) were women and 151 (27.0%) were men. Two participants did not indicate their gender. Participants' ages ranged from

17 to 62 years, with a mean of 25.69 (standard deviation [*SD*] = 9.05). In this group, there were 121 (21.6%) first-year students, 81 (14.5%) sophomores, 149 (26.7%) juniors, 112 (20.0%) seniors, and 95 (17.0%) graduate students. A variety of study majors was represented in the present study: psychology and sociology (22.5%); elementary education (20.8%); counseling (9.7%); fine arts (9.2%); business (5.9%); medical sciences (5.7%); engineering (5.0%); and physical sciences (3.9%). In terms of ethnicity, 78.0% were white; 14.5%, African American; and 4.1%, Hispanic. In the sample, 229 (40.97%) students were not enrolled in any mathematics course.

Sample 2

The modified RMARS model was cross-validated on Sample 2. The second sample included 246 college students who were enrolled in mathematics courses at several southwestern state universities in the United States. In this group, there were 183 (74.4%) women and 63 (25.6%) men, of whom 2 (.8%) were first-year students; 20 (8.1%), sophomores; 74 (30.1%), juniors; 95 (38.6%), seniors; and 55 (22.4%), graduate students. Participants' ages ranged from 18 to 55 years, with a mean of 27.08 (*SD* = 8.72). Most (71.1%) of the students in Sample 2 were majoring in social sciences; the remainder included 6.5% in educational administration, 2% in secondary and higher education, 1.2% in elementary and secondary education, 9.3% in business, 6.5% in physical sciences, and .8% in counseling.

Instrument

A survey packet that included demographic items (i.e., age, gender, ethnicity, grade point average, major, college status, etc.), two rating questions, and the RMARS was used to collect data in the present study. The request "Indicate your GENERAL mathematics anxiety level by entering any number between 0 and 100, where 0 is 'no math anxiety at all' and 100 is 'the severest math anxiety possible'" was used to assess perceived general mathematics anxiety levels. "Indicate your CURRENT mathematics anxiety level by entering any number between 0 and 100, where 0 is 'no math anxiety at all' and 100 is 'the severest math anxiety possible'" was used to assess current mathematics anxiety levels. Higher scores referred to higher general and current mathematics anxiety, respectively.

Procedure

Permission to use and duplicate the RMARS was obtained from its author. Survey packets that included demographic items, two rating questions, an additional consent form, and the RMARS were assembled. Course instructors were informed about the purpose of the study and given a sample survey packet. If the instructors agreed, a schedule for the administration was made. Prospective participants were contacted in their classes and informed about the study. To ensure confidentiality, participants were asked not to write identifying information on the packets.

Students completed the packets during the first or last 20 minutes of the class time. After the completion of the packets, participants were debriefed. Two main statistical software programs were used in the study: the Statistical Procedures for Social Sciences (SPSS) 10.0 (1998) and the Equations 5.5 (EQS; Bentler, 1992; Bentler, 1995; Bentler & Wu, 1993). Data were coded onto the SPSS 10.0 database and were arranged so that they could be transferred onto the EQS.

Design

The hypothesized confirmatory factor analysis model consisted of a total of 81 parameters, of which 53 were free and 28 were fixed to nonzero. The model included 25 dependent variables, 25 independent variables, and 3 latent variables (factors). The first 15 items of the RMARS were set to load on the mathematics test anxiety factor. Five items (16–20) were set to load on the numerical task anxiety factor, and the last five items (21–25) were set to load on the mathematics course anxiety factor. Thus, the present confirmatory factor analysis model was overidentified, because it had a total of 300 ($25 * [(25 - 1)/2]$) data points, of which only 28 were fixed to nonzero, thus leaving the model with $df = 272$.

Analysis

Data were screened for the assumptions of parametric statistics and structural equation modeling techniques. These assumptions were normality, homoscedasticity, and linearity. Assumptions were investigated visually, numerically, and statistically. Finally, distributions were also examined for multivariate normality and linearity. Multivariate normality was investigated through the Mardia (1970, 1974) index of multivariate skewness.

A confirmatory factor analysis model was specified, identified, and tested for fit. The variance-covariance matrix was used to analyze the associations among the variables. Parameter estimates were based on the robust estimation method. Also, Satorra-Bentler (1988a, 1988b) correction was used. These methods adjusted the maximum likelihood estimation with multivariate nonnormality. Parameter estimations were followed by the evaluation of model fit. Evaluation of model fit tested a null hypothesis of no difference between the model-implied covariance matrix and the observed covariance matrix (Yamada & Pandey, 1995). Model fit was evaluated whether or not the three absolute fit indices (a nonsignificant χ^2, an Adjusted Goodness-of-Fit Index > .90, and Root Mean Square Error of Approximation < .10) and the three incremental fit indices (a Normed Fit Index > .90, a Nonnormed Fit Index > .90, and an Adjusted Comparative Fit Index > .90) showed a "good fit" (Bentler, 1990; Bentler & Bonett, 1980). The standardized regression weights and the squared multiple correlations were computed to assess each observed variable's contribution to its respective latent variable (factor). All the regression weights and squared multiple correlations were evaluated at $p < .05$.

When the hypothesized confirmatory factor model did not reach the above-mentioned criteria, an exploratory factor analysis was conducted.

In the exploratory factor analysis, principal component extraction method and varimax rotation were used to discover underlying component structures of the 25 mathematics anxiety items.

Results

In Sample 1, reported grade point averages ranged from 1.00 to 4.00, with a mean of 3.19 (SD = .53). Students also rated their general and current mathematics anxiety levels on a scale between 0 and 100, higher scores referring to more general and current mathematics anxiety levels. General mathematics anxiety ratings ranged from 0 to 100, with a mean of 49.69 (SD = 29.87). Current mathematics anxiety ratings ranged from 0 to 100, with a mean of 47.74 (SD = 33.53). In sample 2, reported grade point averages ranged from 2.00 to 4.00, with a mean of 3.26 (SD = .51).

Sample 1 and Sample 2 were compared on the study variables. Two samples were statistically equivalent on the total RMARS scores, $t_{(757)}$ = .52, p < .52, as well as the three subscales (Mathematics Test Anxiety, $t_{(757)}$ = .69, p < .49; Numerical Task Anxiety, $t_{(757)}$ = –.66, p < .51; and Mathematics Course Anxiety, $t_{(757)}$ = 1.05, p < .29).

Confirmatory Factor Analysis

The hypothesized confirmatory factor analysis model included three latent variables: Mathematics Test Anxiety, Numerical Task Anxiety, and Mathematics Course Anxiety. The first 15 items of the RMARS were set to load on the mathematics test anxiety factor. Five items (16–20) were set to load on the numerical task anxiety factor, and the last five items (21–25) were set to load on the mathematics course anxiety factor. The model consisted of a total of 81 parameters, of which 53 parameters were free and 28 were fixed to nonzero. The model included 25 dependent variables (RMARS items 1–25), 25 independent variables (25 independent errors of the 25 RMARS items), and 3 independent factors (Mathematics Test Anxiety, Numerical Task Anxiety, and Mathematic Course Anxiety).

All the parameters related to the dependent variables were set free to be estimated. The parameters of RMARS01, RMARS16, and RMARS21 were fixed to unity. Thus, the confirmatory factor analysis model was an overidentified model because it had a total of 300 ([25 $*$ (25 – 1)/2]) data points, of which only 28 were fixed to nonzero, leaving the model with df = 272. The Maximum Likelihood (ML) and Robust estimations were used to estimate the free parameters of the model.

The goodness-of-fit summary was obtained for the hypothesized model through both the ML and Robust estimation method. Under the Robust estimation method, the χ^2 associated with the model of independence (i.e., variables are uncorrelated) was rejected, $\chi^2_{(300)}$ = 10168.81, p < .001. Marginal support was found for the hypothesized model in terms of fit statistics: Normed Fit Index (Bentler & Bonett, 1980); Bentler-Bonett Nonnormed Fit Index (Bentler & Bonett); Comparative Fit Index (Bentler, 1990); Incremental Fit Index (Bollen, 1989); Goodness of Fit Index

(Jöreskog & Sörbom, 1988); Adjusted Goodness of Fit Index (Jöreskog & Sörbom); or Root Mean Square Error of Approximation (Steiger, 1990). Table 1 shows several fit indices for the original RMARS model under the ML and Robust estimation methods. Because fit indices did not support the factor structure of the hypothesized model, estimated parameter values or standardized measurement equations were not reported.

Table 1

Fit Indices for the Confirmatory Factor Model Under Maximum Likelihood and Robust Estimations

	Models Tested									
	Original Model (n = 559)		Modified Model (n = 559)		Cross-validated (n = 246)		Men (n = 214)		Women (n = 589)	
Fit Indices	ML[a]	Robust	ML	Robust	ML	Robust	ML	Robust	ML	Robust
χ^2 *	1451.24	1451.24	881.66	806.15	480.17	337.66	408.39	314.78	973.10	742.69
Normed Fit Index	.86	.86	.90	.90	.87	.89	.87	.89	.90	.90
Nonnormed Fit Index	.87	.87	.91	.90	.90	.93	.91	.94	.90	.91
Comparative Fit Index	.88	.88	.92	.92	.91	.94	.92	.94	.91	.92
Incremental Fit Index	.88	.88	.92	.92	.91	.94	.92	.94	.91	.92
Root Mean Square Error of Approximation	.10	.09	.09	.09	.09	.07	.09	.06	.06	.07
Goodness-of-Fit Index (GFI)	.76			.89		.83	.83		.85	
Adjusted GFI	.71			.81		.79	.79		.81	

[a] ML = Maximum Likelihood. * $p < .001$.

Exploratory Factor Analysis

To improve the fit of the hypothesized mathematics anxiety model, 25 items of the RMARS were tested through an exploratory factor analysis. First, Bartlett's (1954) test of sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy (1974) were examined for the factorability of the current correlation matrix. Factor analysis is appropriate when the test of sphericity is significant and the sampling adequacy is over .60, which indicate that correlations are not zero (Tabachnick & Fidell, 2001). Both Bartlett's test of sphericity (approx. $\chi^2_{(300)} = 110011.05$, $p < .0001$) and the Kaiser-Meyer-Olkin measure of sampling adequacy (.95) suggested that the correlation matrix was appropriate for factor analysis.

To extract the maximum amount of variance, principal component analysis was used with a varimax rotation. Extraction resulted in three components with eigenvalues greater than 1.00 (Table 2). In addition, the scree test (Cattell, 1966) suggested a three-component solution. The three components, the amount of variance accounted for by the components (communalities), pattern matrix, and the proportion of variance in the set accounted by the components are shown in Table 2.

A total of 66.08% of the variance was accounted for by the three components. The communality scores indicated the percentage of variance accounted for by the three components. A variable should have at least a score of .45 for inclusion in interpretation (Tabachnick & Fidell, 2001). In the model, the communalities ranged from .47 to .90.

Table 2

Factor Component Matrix and Communality Coefficients for the RMARS Items

Variables	h^2	Component Matrix [a, b] 1	2	3
RMARS01: Studying for a math test	.62	.74 (.72)	.25 (.45)	(.16)
RMARS02: Taking the mathematics section of college entrance exam	.49	.69 (.61)	(.40)	(.26)
RMARS03: Taking an exam (quiz) in a math course	.70	.83 (.82)	.23 (.31)	(.21)
RMARS04: Taking an exam (final) in a math course	.63	.83 (.86)	(.24)	(.17)
RMARS05: Picking up math textbook to begin working on a homework assignment	.58	.46 (.40)	.53 (.60)	.17 (.39)
RMARS06: Being given homework assignments of many difficult problems that are due the next class meeting	.61	.54 (.67)	.41 (.34)	(.25)
RMARS07: Thinking about an upcoming math test 1 week before	.76	.65 (75)	.42 (.38)	.15 (.19)
RMARS08: Thinking about an upcoming math test 1 day before	.72	.83 (.88)	.23 (.30)	.12
RMARS09: Thinking about an upcoming math test 1 hour before	.58	.83 (.88)	.14 (.24)	
RMARS10: Realizing you have to take a certain number of math classes to fulfill requirements in your major	.58	.62 (.60)	.42 (.53)	.14 (.20)
RMARS11: Picking up math textbook to begin a difficult reading assignment	.52	.55 (.55)	.40 (.61)	.15
RMARS12: Receiving your final math grade in the mail	.55	.72 (.76)	.17 (.34)	(.18)
RMARS13: Opening a math or stat book and seeing a page full of problems	.62	.57 (.62)	.52 (.50)	.17 (.16)
RMARS14: Getting ready to study for a math test	.65	.52 (.74)	.49 (.38)	.17 (.23)
RMARS15: Being give a “pop” quiz in a math class	.65	.78 (.68)	(.45)	(.27)
RMARS16: Reading a cash register receipt after your purchase	.47	(.17)	.23 (.29)	.64 (.23)
RMARS17: Being given a set of numerical problems involving addition to solve on paper	.83	.13 (.15)	.20 (.25)	.88 (.87)
RMARS18: Being given a set of subtraction problems to solve	.87	(.15)	.19 (.15)	.91 (.93)
RMARS19: Being given a set of multiplication problems to solve	.90	.16 (.17)	.14 (.19)	.92 (.92)
RMARS20: Being given a set of division problems to solve	.80	.18 (.22)	.16 (.22)	.86 (.87)
RMARS21: Buying a math textbook	.52	(.28)	.69 (.78)	.21 (.18)
RMARS22: Watching a teacher work on an algebraic equation on the blackboard	.65	.30 (.33)	.67 (.69)	.33 (.25)
RMARS23: Signing up for a math course	.76	.33 (.47)	.80 (.68)	.16 (.19)
RMARS24: Listening to another student explain a math formula	.62	.26 (.39)	.71 (.68)	.24 (.23)
RMARS25: Walking into a math course	.71	.30 (.44)	.78 (.74)	(.20)
Eigenvalue		11.35	3.46	1.71
% of accounted for variance		45.42	13.84	6.82

[a] Loadings smaller than .10 were suppressed.
[b] Within parentheses are Bowd and Brady (2002) loadings.

To investigate unique relationships (i.e., uncontaminated by overlap of components) between the components and variables, a component matrix was used. Variables that had component loadings lower than .60 were eliminated; there were five such variables.

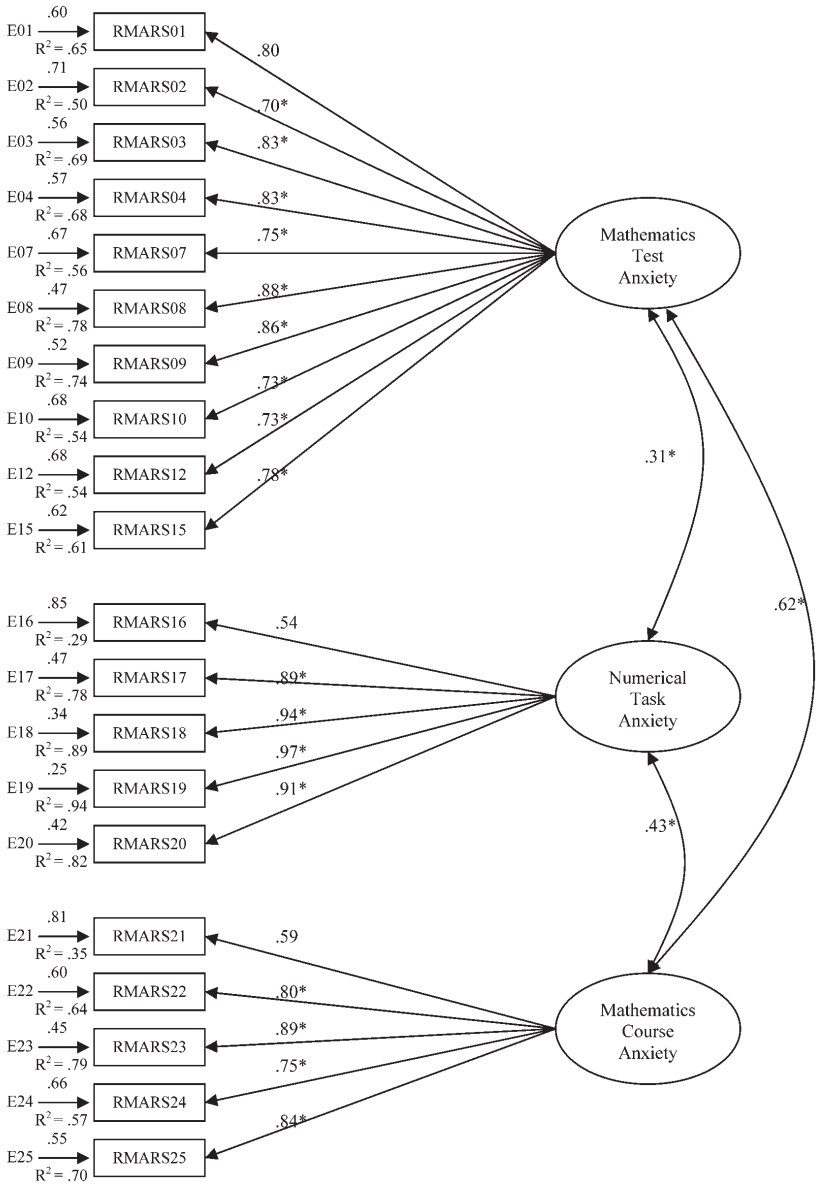

Figure1. Parameter estimates and standardized coefficients for the modified model. * $p < .05$.

Confirmatory Factor Analysis of the Modified Model

Five variables had component loadings smaller than .60 in the original RMARS model, and exploratory factor analysis suggested their elimination. Therefore, the items "picking up math textbook to begin working on homework assignment"; "being given homework assignments of many difficult problems that are due the next class meeting"; "picking up math textbook to begin a difficult reading assignment"; "opening a math or stat book and seeing a page full of problems"; and "getting ready to study for a math test" were dropped from the model. Thus, the confirmatory factor analysis of the modified model (Figure 1) included three latent variables (components): Mathematics Test Anxiety (10 measured variables), Numerical Task Anxiety (5 measured variables), and Mathematic Course Anxiety (5 measured variables). The model consisted of a total of 66 parameters, of which 43 parameters were free and 23 were fixed to nonzero.

All the parameters related to the dependent variables were set free to be estimated. The parameters of RMARS01, RMARS16, and RMARS21 were fixed to unity based on the pattern coefficients. The confirmatory factor analysis model was an overidentified model, with df = 190. The ML and Robust estimations were used to estimate the free parameters of the model.

The goodness-of-fit summary was obtained for the modified model through both the ML and Robust estimation methods (Table 1). The χ^2 associated with the model of independence (i.e., variables are uncorrelated) was rejected, $\chi^2_{(190)} = 7726.53$, $p < .001$. Because the fit indices supported the factor structure of the modified model, standardized coefficients were computed (see Figure 1). Figure 1 shows that all nondirectional relationships among mathematics test anxiety, numerical anxiety, and mathematics course anxiety were significant. Moreover, measured variable loading ranged from .70 to .88 in the Mathematics Test Anxiety; from .54 to .97 in the Numerical Task Anxiety, and from .59 to .89 in the Mathematics Course Anxiety. For the Mathematics Test Anxiety, the largest amount of variance was accounted for by "thinking about an upcoming math test 1 day before" (R^2 = .78); "being given a set of multiplication problems to solve" (R^2 = .94) for the Numerical Task Anxiety; and "signing up for a math course" (R^2 = .79) for the Mathematics Course Anxiety.

Cross-validation

Researchers suggest validating a modified structural model on a sample different from the one on which the modified model is obtained (Tabachnick & Fidell, 2001). Therefore, Sample 2 was used for cross-validity purposes. Table 1 shows the goodness-of-fit summary obtained for the cross-validated model through both the ML and Robust estimation methods. Original confirmatory factor analysis model was not a good fit; however, the modified model showed a much better fit. When this model was tested on another sample (Sample 2), the cross-validated model's fit indices indicated an acceptable fit of the model as well. Analyses were

continued for model improvement by the Wald and Lagrange multiplier tests (Bentler, 1992, 1995; Bentler & Wu, 1993). Wald test results suggested dropping no parameter; however, Lagrange multiplier test results suggested adding four parameters: RMARS07, Course Anxiety-χ^2 = 54.31, $p < .0001$; RMARS10, Course Anxiety-χ^2 = 53.46, $p < .0001$; RMARS21, Test Anxiety-χ^2 = 40.74, $p < .0001$; and RMARS22, Numeric Anxiety-χ^2 = 31.79, $p < .0001$.

In addition to testing the factorial structure of the modified model, two separate confirmatory factor analyses were performed for each gender to investigate whether this factorial structure was invariant or not. For this purpose, two samples (Sample 1 and Sample 2) were combined. In the combined sample, there were 214 men and 589 women. For men, both ML and Robust estimation methods showed fit results similar to those obtained with the cross-validated model. For women, fit indices were a bit higher than men's results. However, a comparison of the fit indices between these two samples shows that the factorial structure was invariant across gender.

Concurrent Validity

Concurrent validity was investigated through concurrent validity coefficients for the original and modified RMARS models. Students were asked to rate their general current mathematics anxiety levels on a scale of 0 to 100, where higher scores referred to higher levels of anxiety. Table 3 shows that all concurrent validity coefficients were significant. Both the total RMARS and subscale scores correlated higher with perceived general mathematics anxiety scores than those of perceived current mathematics anxiety scores.

Table 3

Concurrent Validity Coefficients of the RMARS

	Concurrent Validity Coefficients[a]			
	General Mathematics Anxiety		Current Mathematics Anxiety	
Variables	Original Model	Modified Model	Original Model	Modified Model
RMARS	.70	.70	.65	.66
Mathematics Test Anxiety	.69	.69	.65	.65
Numerical Task Anxiety	.31	.31	.31	.31
Mathematics Course Anxiety	.52	.52	.47	.47

[a]All coefficients are significant at $p < .01$

Reliability

Spielberger et al. (1983) noted that due to the transitory nature of anxiety states, particularly in mathematics anxiety, test-retest reliability techniques would not be suitable. Therefore, internal consistency and split-half reliability analyses were performed to reveal the consistency of the RMARS items (Table 4).

Table 4

Internal Consistency, Split-Half, and Parallel-Model Reliability Coefficients

	Reliability					
	Internal Consistency[a]			Split-Half[b]		
	Original Model	Modified Model	Cross-validated	Original Model	Modified Model	Cross-validated
RMARS	.95 (.95)	.94 (.94)	.92 (.94)	—	—	—
Test Anxiety	.95 (.95)	.94 (.94)	.94 (.94)	.95	.94	.95
Numerical Anxiety	.92 (.92)	.92 (.92)	.90 (.92)	.90	.90	.88
Course Anxiety	.88 (.88)	.88 (.88)	.86 (.88)	.89	.89	.86

[a] Within parentheses are unbiased estimates of parallel-model reliability coefficients.
[b] Unequal and equal-length Spearman-Brown coefficients were used.

Split-half reliability coefficients were not computed for the total RMARS scores, because each subscale measured different aspects of mathematics anxiety. For the subscales' split-half reliability, unequal-length Spearman-Brown coefficients were used when the subscales had odd numbers of variables and equal-length Spearman-Brown coefficients were used when the subscales had even numbers of variables. The average interitem correlation for the total scale was .41 (.60 for Mathematics Test Anxiety; .72 for Numerical Task Anxiety; and .60 for Mathematics Course Anxiety).

Discussion

A psychometrically sound, but also efficient, measurement of mathematics anxiety is the first step in developing appropriate and effective intervention strategies to deal with mathematics anxiety. The present study was an attempt to test the factorial structure of a commonly used mathematics anxiety scale and thus contribute to the knowledge of mathematics anxiety research.

The original 25-item RMARS was subjected to a confirmatory factor analysis, and the factorial structure of the model was not confirmed. None of the fit indices was above the suggested cutoff criteria (.90), which suggested that the theoretical model suggested by the RMARS did not fit well to the model derived from the data. Consequently, it was hoped that an exploratory factor analysis might reveal which, if any, of the items of the original RMARS was not relevant to the scale.

Principal component analysis still showed that the RMARS was a three-dimensional construct; however, not all 25 items loaded on the components. Specifically, five test anxiety items did not load with the Mathematics Test Anxiety subscale. Neither did they load on the other two components. Therefore, the following five items were dropped from the scale: "picking up math textbook to begin working on homework assignment"; "being given homework assignments of many difficult problems that are due the next class meeting"; "picking up math textbook to begin a difficult reading

assignment"; "opening a math or stat book and seeing a page full of problems"; and "getting ready to study for a math test."

These items would appear not to be directly related to test-taking circumstances. For example, picking up a textbook to work on a homework assignment bears little relationship to taking a mathematics test. Similarly, being given homework assignments is not related to test taking. It might be related to mathematics course anxiety but did not load on that component either. It seems that these items are not related to Mathematics Test Anxiety. In addition, there is a problem with the item "opening a mathematics or statistics book and seeing a page full of problems." This item ignores the possible differences that might exist between the concept of statistics anxiety and mathematics anxiety and assumes the two to be identical. However, recent research shows that this assumption is not correct (e.g., Baloğlu, 2001; Baloğlu, 2004a). Among the five dropped items, "getting ready to study for a mathematics test" seems to be relevant to test anxiety, but even it is not describing anxiety-provoking situations that might occur under test-taking circumstances.

After these low-loading items were dropped, the remaining items of the RMARS were subjected to a second confirmatory factor analysis. In the second analysis, the modified model fit the data much better and the standardized parameter estimates showed that "thinking about an upcoming mathematics test one day before" loaded highest with the Mathematics Test Anxiety subscale. This item seems to convey the best picture in terms of the intensity of anxiety feelings related to test taking. On the Numerical Task Anxiety component, parameter estimates showed that doing multiplication is the best predictor of someone's numerical anxiety. Similarly, the parameter estimates on the Mathematics Course Anxiety component showed that signing up for a mathematics course was the best indicator of the mathematics course anxiety.

Researchers suggest the testing of modified models on samples (i.e., cross-validation) other than the one on which modification was performed (Tabachnick & Fidell, 2001). Cross-validation lends limited support to model fit. Even though there was a marginal drop in the fit indices in the cross-validated sample, this drop could be related to decrease in sample size (from 559 to 246). Therefore, it can be concluded that cross-validation results were similar to the modified RMARS items in factorial structure. In addition, factorial structure did not vary by gender. Model improvement tests suggested the addition of a parameter from "thinking about an upcoming math test 1 week before," as well as from "realizing you have to take a certain number of math classes to fulfill requirements in your major," to the Course Anxiety component. The results imply that even though these items are most related to test-taking situations, they also have relationships with course component. The other two parameter suggestions were from "buying a math textbook" to the Test Anxiety and from "watching a teacher work on an algebraic equation on the blackboard" to Numeric Anxiety. Similarly, results imply that these two items are most related to course anxiety; however, they might also relate to test anxiety

or numeric anxiety, respectively. The addition of these parameters caused a 2- to 3-point increase in model fit, making the model fit better. Future studies are advised to confirm this information and test the model fit with these parameters.

The exploratory factor analysis part of the current study showed great similarities to and slight differences from that of Bowd and Brady (2002), who studied the factor structure of the RMARS on Canadian seniors in a B.Ed. program. Both studies had similar sample characteristics in terms of age (26 years versus 26 years) and gender distribution (about 1:3 men-to-women ratio in both studies). Study major and grades showed minor differences, in that the present study had students from various majors and grades, including graduate students, whereas Bowd and Brady's (2002) sample had only seniors majoring in education. Both studies used similar methods (i.e., principal component analysis followed by varimax rotation). However, the present study also used CFA to test the underlying factor structure in the RMARS scores. When it comes to the factor structure of the RMARS, the studies had major similarities as well. For example, in both studies, higher percentages of variability in the RMARS scores (66% versus 73%) are accounted for by three components (i.e., Test Anxiety, Numerical Task Anxiety, and Course Anxiety) in comparison with the study by Alexander and Martray (1989). Bowd and Brady (2002) did not report factor loadings in their study; however, their data were re-analyzed for the present study and loadings were reported for future research.

Differences in factor loading between the present study and that of Bowd and Brady (2002) became apparent. Whereas RMARS05 and RMARS06 did not load on any factor in the present study, RMARS05 loaded on Course Anxiety and RMARS06 loaded on Test Anxiety in Bowd and Brady's study. Another discrepancy is that RMARS11 did not load with any factor in the present study; on the contrary, it loaded with the Course Anxiety component in that of Bowd and Brady. Similarly, RMARS13 and RMARS14 did not load with any factor in the present study, but they loaded with Test Anxiety in that of Bowd and Brady.

Bowd and Brady (2002) did not report which of the two RMARS items they dropped; however, we were able to identify only one of the items (RMARS16) that did not load with any factor (< .30) in their study. On the other hand, RMARS16 loaded with Numerical Task Anxiety in the present study. Differences in the factor structures between the two studies, even though they employed seemingly similar samples, might be due to sampling characteristics. It is possible that Canadian and U.S. college students experience mathematics anxiety differently. Moreover, a large portion of the sample in the present study was enrolled in mathematics courses. Bowd and Brady did not collect information regarding which course the sample of their study was enrolled in. When total RMARS scores were compared, Canadian education-majoring seniors were shown to have scored lower (mean = 46.56, SD = 15.78) than the U.S. college students did (mean = 65.51, SD = 18.98). From the present data, we selected U.S. students majoring in elementary education and found

that their mean mathematics anxiety score was even higher (mean = 70.58, SD = 20.84). Therefore, we conclude that Canadian and U.S. students experience mathematics anxiety differently and thus differences in factor structure should be investigated more carefully.

Research findings indicate that students' subjective evaluations of their own anxiety status are related to their objectively measured anxiety scores (e.g., Baloğlu, 2004b). Even though there was not a statistically significant difference between the two, scores were correlated higher with the perceived *general* mathematics anxiety ratings than *current* mathematics anxiety ratings, lending a general support to concurrent validity of the instrument.

Reliability investigations showed that both the total scale and the subscales were highly reliable. Even though the Numerical Task Anxiety and Mathematics Course Anxiety subscales each had five items, reliability coefficients were around .95. In addition, all reliability coefficients were stable with the cross-validated sample. Hence, the instrument seems to be consistent.

In conclusion, the modified RMARS was found to be a valid and reliable measure of college students' mathematics anxiety levels; therefore, it may be used by different professionals to detect and deal with mathematics anxiety. First, mathematics instructors may use it as a screening tool to detect high-risk students in their mathematics courses. Second, counselors may use it as a placement tool to pinpoint specific areas of the problem in mathematics anxiety. Depending on the area of difficulty, different intervention strategies might be implemented. Third, researchers may use the instrument as a research tool to study the relationships between mathematics anxiety and other important factors.

From the findings, the following suggestions were made for future research: First, current literature suggests that mathematics anxiety is a transitory-state construct; therefore, the directions of the RMARS should be modified accordingly as "indicate the amount of anxiety you are *currently* experiencing in each of the listed situations" or "indicate how you feel right now in regard to each of the listed situations." Future studies should investigate the instrument's psychometric properties after this change is made.

Second, due to time and resource constraints, the present study was unable to test concurrent validity of the modified RMARS by correlating its scores with other valid and reliable mathematics anxiety measures, such as the Mathematics Anxiety Rating Scale–Revised (Plake & Parker, 1982). It will also be of significance to correlate the modified RMARS with the original MARS.

Third, the modified RMARS should be tested on other sample groups, such as high school students. Its validity and reliability specific to ethnic minorities should be investigated with larger sample sizes from those groups.

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