Dimensions of Math Anxiety as Measured by the MARS-Brief: Factor Analysis

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Abstract

Because of the complexity of math anxiety, there is no unique measure that reflects the consensus of current thought on this construct that could be used to determine a single, generally agreed-upon estimate of the fraction of the population that is experiencing math anxiety. This study compared the dimension dominating the MARS (Math Anxiety Rating Scale) based instrument (MARS-Brief) with the dimensions dominating its scores. The assumption motivating this study was that if the assessment of math anxiety by MARS-Brief is still relevant, then these two dimensions should align and pertain to anxiety related to manipulation of numbers. This was accomplished by investigating the dimensions underlying the construct of math anxiety and the scale measuring it. The factor analysis used to analyze the data identified two major dimensions: Numerical Anxiety and Math Test Anxiety. The results indicate that the anxiety related to evaluation of one's math ability is more dominant than the one stemming from manipulation of number. This implies that college students' anxiety comes, not necessarily from facing a mathematical task, but rather from being evaluated on one. While the current study recognized two major dimensions of math anxiety that were consistent with the findings in the literature, the results also suggested that these dimensions which seemed to be dominating the scores of the instrument, did not necessarily dominate the measured construct.

Keywords: math anxiety, dimensions, factors, factor analysis, EFA, MARS, MARS-Brief

Definition of Math Anxiety

In today's technological and scientific society, importance of mathematics is highly accentuated. However, in spite of its significance, there is still a high number of students who shy away from "math heavy" courses and terminate certain career paths without ever even embarking on them. One of the biggest hurdles many students face in their academic careers is mathematics, a discipline that is intertwined in almost every natural and social science, as well as many health and business related fields. Fears related to this fundamental area of study continue to be seen as a major cause for not pursuing academic goals which rely heavily on mathematics, therefore minimizing vocational opportunities for individuals harboring these feelings of anxiety, commonly referred to as math anxiety.

As a result of such views, math anxiety is often the reason used for the poor performance of a wide range of individuals in settings where math-related skills are essential. Math anxiety does not have a unique description, but rather it has been described using various definitions. Math anxiety is described by Tobias (1978) as "sudden death" (p. 46). Kogelman and Warren (1979) refer to it simply as an adverse reaction to mathematics, while Byrd (1982) says it is the feeling of anxiety "when confronted with mathematics in any way" (p. 38). One of the most commonly used definitions of math anxiety is the one given by Richardson and Suinn (1972), who state that math anxiety "involves feelings of tension and anxiety that interfere with manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (p. 551). The current study employed this definition of math anxiety. The reason for selecting this definition over numerous others available in the literature is dual. First of all, this definition has been used most frequently in the research of this phenomenon, and secondly, the instrument used to measure math anxiety in this study is based on this definition.

Math anxiety, a condition frequently used by many students, teachers, and administrators to explain feelings of tension and fear when faced with mathematics, has been investigated for decades. However, this investigation is anything but exhausted. This is evident in not only the existence of various definitions of math anxiety, but also a lack of consensus regarding the relationship between this phenomenon and some of its presumed predictors. Considering that math anxiety has been seen as a cause of poor math performance and avoidance behavior, it is necessary to attempt to understand the nature of math anxiety. This can be achieved, at least in part, by identifying and understanding the dimensions underlying this construct. In order for this to be adequately accomplished, the selection of a relevant instrument measuring math anxiety is critical.

Prevalence and Dimensions of Math Anxiety

Because of the complexity of this phenomenon, the variability in the definitions used to describe it, and the wide range of symptoms reported by those who experience difficulty while doing mathematics, there is no unique measure that reflects the consensus of current thought on this construct that could be used to determine a single, generally agreed-upon estimate of the fraction of the population that is experiencing math anxiety. Regardless of the exact number of affected students, the existing literature suggests that math anxiety is prevalent on college campuses (Betz, 1978; Khatoon & Mahmood, 2010; Perry, 2004). However, none of the math anxiety scales used to measure this condition offers a clear description of what constitutes a math anxious student. For example, the creators of the Math Anxiety Rating Scale, MARS (Richardson & Suinn, 1972), the most prominent and used math anxiety instrument to this date, provide a correspondence between MARS scores and math anxiety (higher MARS scores are indicators of higher levels of math anxiety), however, no distinct cutoff scores are suggested.

Because the maximum scores attainable on the instruments used in the studies investigating math anxiety vary (due to a different number of instrument items), it may be necessary to consider fractional mean scores of the scales. Fractional mean scores are defined as ratios of mean scores and maximum scores. An overview of the studies utilizing the MARS or its modified versions revealed a range of fractional mean scores between .304 and .601 (Bessant, 2005; Brush, 1978; Gresham, 2007; Hopko, 2003; Hunsley, 1987; Malinksy, Ross, Pannells, & McJunkin, 2006; Morris, Kellaway, & Smith, 1978; Plake & Parker, 1982; Resnick, Viehe, & Segal, 1982; Richardson & Suinn, 1972; Vinson, 2001; Woodard, 2004). While these scores may be interpreted to indicate the presence of math anxiety, it is not clear how strong the effects are on students supposedly suffering from this condition. Further, majority of these studies fail to comment on these relatively low average scores or offer any plausible explanations of the findings that appeared to contradict anecdotal evidence and common beliefs of prevalence of math anxiety among college students.

Numerous studies have been conducted in order to identify the distinct dimensions underlying math anxiety as measured by the MARS and various MARS based instruments. The most common method used in the process of identification of math anxiety dimensions has been exploratory factor analysis. Factor analysis "seeks to discover if the observed variables can be explained largely or entirely in terms of a much smaller number of variables called factors" (Darlington, n.d. p.1). However, the same observed variables may be explained in terms of various factors as a result of different factor analyses. This is due to the type of steps involved in the process of factor analysis, which allow for different approaches among researchers. For example, one of the steps in the process of factor analysis is selecting the number of factors for inclusion. While the optimal way to decide on the number of factors to be extracted should be statistically reliable, this decision may be influenced by certain hypothesis, or based on various, less dependable methods of determining this number (DeCoster, 1998). Differences in resulting factors may also be a result of different extraction methods used to extract the initial set of factors or numerous types of rotations used for defining factors (Charles, 1995; DeCoster, 1998). Unfortunately, although most researchers identify two or three factors (dimensions) of the MARS, they rarely provide any rationale regarding the number of their chosen factors, method of extraction, or other steps involved in this type of analysis. This prevents us from accepting their findings or generalizing them with a high degree of confidence. In this study we include a rationale for steps included in factor analysis of the MARS-Brief in our attempt to examine dimensionality of math anxiety as measured by this instrument.

Simply stated, investigating the dimensionality of math anxiety means identifying the factors that make up this construct. Better understanding of the multiple facets of this phenomenon would provide a better insight into the nature of math anxiety. Accomplishing this would be very beneficial in preventing, or at least minimizing the impact of this malady. Numerous studies were conducted in order to identify distinct dimensions of math anxiety as measured by the Mathematics Anxiety Rating Scale (MARS) and instruments based on the MARS. For example, two factors, Mathematical Test Anxiety and Numerical Anxiety, were identified as a result of a factor analysis of the MARS (Rounds & Hendel, 1980). The Mathematical Test Anxiety factor deals with items related to evaluation of math ability, while the Numerical Anxiety factor includes items pertaining to manipulation of numbers in everyday settings. The factor related to the process of assessing one's mathematical knowledge was also recognized by Brush (1978), who identified two (although differently labeled) dimensions as a result of factor analysis: Problem-Solving Anxiety and Evaluation Anxiety. Similar results were also reported by Plake and Parker (1982), who identified Learning Mathematics Anxiety and Mathematics Evaluation Anxiety. Alexander and Cobb (1989) also defined two factors, Math Test/Course Anxiety and Numerical Task Anxiety. On the other hand, Resnick, Viehe, and Segal (1982) identified three independent dimensions: Evaluation Anxiety, Social Responsibility Anxiety (Social Responsibility Anxiety relates to mathematical processes in social settings), and Arithmetic Computation Anxiety. An earlier study also isolated three subscales as a result of factor analysis of the MARS: Math Test Anxiety, Math Studying Anxiety, and Math Class Anxiety (Morris, Kellaway, & Smith, 1978). While all of these studies employed factor analysis in their investigation of dimensionality of math anxiety, they fail to report any significant information regarding the actual process of this analysis. Their reports concerning the implications of the identified dimensions underlying math anxiety are beneficial, however, a lack of rationale for the performed factor analysis steps make it difficult to explain disagreements in their findings.

While the results of the above mentioned studies support the notion that math anxiety is a multidimensional construct, there is no evidence that the MARS encompasses the entire range of dimensions comprising this phenomenon. It is not that there are two, three, or more underlying dimensions of math anxiety, but rather the MARS taps into that many. This distinction is not always made in the literature. It needs to be emphasized that "the complexity of mathematics anxiety cannot be limited to factors identified in the MARS" (Bessant, 2005, p. 327). This belief led to a development of multiple instruments designed to identify, not only the known factors underlying math anxiety, but possibly the ones not yet presented in the literature.

A lack of agreement on what constitutes math anxiety has resulted in a creation of various, non-interchangeable scales that appeared to measure different aspects of this phenomenon. For example, a factor analysis of three major math anxiety scales resulted in identification of six factors corresponding to six dimensions underlying the construct (Kazelskis, 1998). Interestingly, none of these factors were common to all the scales, and surprisingly, the Numerical Anxiety factor accounted for the smallest part of the variance of the identified factors. This raises two important questions. Is it possible that math anxiety is an extremely intricate construct, spanning multiple dimensions which have not yet been encompassed by one single instrument? Or do the existing instruments simply fail to capture the full nature of math anxiety? Recalling that what is today recognized as math anxiety stemmed from number anxiety (Dreger & Aiken, 1957), if the factor of numerical anxiety is not present or is not deemed significant by some of current instruments, can they still be seen as adequate measures of math anxiety?

While the studies employing factor analysis of the MARS or its modified versions did not necessarily identify the same dimensions, they all recognized factors related to the evaluation of one's math ability and manipulation of numbers. In the majority of the studies, the Math Test Anxiety factor had the largest eigenvalue (ranging from 13.02 to 32.63) and accounted for the greatest part of the variance (up to 59.2%) compared to the other factors (Alexander & Cobb, 1989; Alexander & Martray, 1989; Bessant, 2005; Plake & Parker, 1982; Resnick, Viehe, & Segal, 1982; Rounds & Hendel, 1980; Suinn & Winston, 2003). These findings suggest that the factor pertaining to assessment of mathematics, most frequently labeled Math Test Anxiety, seemed to dominate the MARS based instruments. However, not all of these studies investigated the scores on the identified major subscales of a MARS based instrument, hence causing difficulties in determining which dimension is the prevalent one.

Purpose of the Study

The purpose of this study is to identify a dimension of math anxiety (as measured by MARS-Brief) that dominates the instrument and determine if this dimension aligns with the one dominating the scores on this instrument. The assumption motivating this study is that if the assessment of math anxiety by MARS-Brief is still relevant, then the dimension dominating the instrument (dimension corresponding to the factor with the largest eigenvalue and accounting for the largest percentage of variance) should also dominate the scores on this instrument. Furthermore, if this instrument truly measures math anxiety, than this prevalent dimension should pertain to manipulation of numbers in various settings. Subsequently, the goal of the study is to determine if there is a need for a more, in-depth investigation of the dimensions underlying the construct of math anxiety, rather than the scales measuring it, and based on that inquiry suggest either the development of an instrument that will encompass more of aspects of this phenomenon or propose the possible need for a shift in the direction of research in math anxiety.

Instrument

In this study, math anxiety was measured by the Math Anxiety Rating Scale – Short Version[1] (Suinn & Winston, 2003). This scale, also commonly referred to as MARS-Brief, is a shorter, 30-item version of the original MARS developed by Richardson and Suinn in 1972. MARS-Brief (as any other MARS based instrument) measures math anxiety as defined by Richardson and Suinn (1972). The target population includes adults, but this instrument has been mostly used in assessing math anxiety in college students. The participant responses on MARS-Brief can vary from 'not at all' (which is interpreted as a score of "1") to 'very much' (which is interpreted as a score of "5"). The scores can therefore range from 30 to 150, with the supposed interpretation that higher scores correspond to higher levels of math anxiety. Created in 2003 by Suinn and Winston, this scale supposedly taps into the major dimensions of MARS: Mathematics Test Anxiety and Numerical Anxiety.

To support the validity of the MARS-Brief scores, it is also beneficial to examine the psychometric data associated with the original scale, MARS. For example, the test-retest reliability coefficient for MARS scores was calculated to be 0.85 for a sample of 30 students retested after 7 weeks and 0.78 for a sample of 119 students retested after 2 weeks (Richardson & Suinn, 1972). These are comparable to reliability coefficients reported for other scales used in practice (Suinn, Eddie, Nicoletti, & Spinelli, 1972). Further, the average intercorrelation of the instrument items was determined to be high as demonstrated by the value of 0.97 reported for the coefficient alpha.

Reliability and validity of scores on the shorter version, MARS-Brief, were consistent with reliability and validity of the scores on the original scale, MARS (see Suinn & Winston, 2003 for details). The scores on the MARS-Brief correlated significantly with the scores on the MARS ($r = 0.92$ at week 1 and $r = 0.94$ at week 2, $p < .001$). As predicted, high scores on MARS-Brief negatively correlated with grade point average in mathematics courses. Additionally, these scores were negatively correlated with mathematics or mathematics related choices for a major (Suinn & Winston, 2003). The results of factor analysis of the MARS-Brief were consistent with the findings of the researchers who identified Math Test Anxiety and Numerical Anxiety as two major dimensions underlying math anxiety (Alexander & Cobb, 1987; Rounds & Hendel, 1980). Specifically, the Math Test Anxiety factor accounted for 59.2% of the variance, while the Numerical Anxiety factor accounted for 11.1% of the variance, with eigenvalues of 13.02 and 2.44 respectively (Suinn & Winston, 2003). Suinn and Winston did not, however, report the scores on the two resulting subscales.

While the psychometric evidence supporting the use of MARS and MARS based instruments in measuring math anxiety in college students may be questioned, these instruments have been

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[1] MARS-Brief items were first published in Suinn, R.M. & Winston, E.H. (2003). The Mathematics Anxiety Rating Scale, a brief version: Psychometric data. Psychological Reports, 92, 167-173. Reprinted here with the permission. © Psychological Reports 2003.

frequently used in the study of this phenomenon and have been accepted as one of the most adequate scales for this purpose.

Sample and Data Collection

The population of interest to this study consisted of all undergraduate students enrolled in first and second year mathematics courses at open enrollment institutions. The study took place in an open-enrollment, public university located in Northeast Ohio, in a community of approximately 200,000 people. In order to choose a representative sample, a stratified, clustered sampling process was employed. Two sections of each of the seven first and second year mathematics courses were selected to participate in the study. The courses included Intermediate Algebra, College Algebra, Excursions in Mathematics, Precalculus, Calculus with Business Applications, Analytic Geometry Calculus I, and Analytic Geometry Calculus II. All undergraduate students majoring in natural sciences have to complete at least College Algebra (with Intermediate Algebra preceding this course for some, less prepared, students), students majoring in STEM disciplines are required to complete a calculus course (usually at least Calculus I and II), and non-science majors may choose to complete one of non-algebra based courses, such as Excursions in Mathematics. Prior research suggests that students enrolled in lower level math courses are more likely to suffer from math anxiety than students in higher level math courses (Betz, 1978; Brush, 1978). The lower level math courses are usually the ones required for either meeting the general education math requirement or advancing toward that course. Considering that 57.29% of the selected participants in this study were enrolled in a course below calculus, and taking into the account the evidence of the existence of math anxiety even in higher level math courses (Betz, 1978; Khatoon & Mahmood, 2010; Perry, 2004), the assumption was that the sample was likely to be math anxious.

The students enrolled in the selected courses were administered the MARS-Brief during the first week of the fall semester during their regularly scheduled class times. Their participation was voluntary and they did not receive any incentives for completing the survey. The produced sample was modified to include only undergraduate students, while excluding any graduate students, students auditing the course, and post secondary students (high school students enrolled in college courses) resulting in a sample size of n = 473. Majority of the sample, 82.45%, consisted of freshmen and sophomore students. There were 181 female (38.27%) and 292 male students (61.73%), with age ranging from 17 to 46 years (average age = 20.1 years).

Factor Analysis of the MARS-Brief

Exploratory factor analysis (EFA) was performed on the correlation matrix in order to indentify underlying dimensions (factors) of math anxiety as measured by 30 items comprising the MARS-Brief. A high chi-square statistics resulting from the Barlett test of sphericity coupled with the Kaiser-Meyer-Olkin measure of sampling adequacy (where the MSA value for each variable was above 0.90) indicated that EFA is a suitable analysis method for the collected data.

The number of factors to be extracted was determined by conducting parallel analysis (Table 1). Parallel analysis is considered to be one of the most accurate methods for determining the number of factors selected for extraction (Henson & Roberts, 2006). Due to a high importance of extracting the appropriate number of factors, the use of multiple rules for determining this number is strongly recommended (Thompson & Daniel, 1996). The Cattel's scree test, shown in Figure 1, confirmed that two factors needed to be extracted. This was subsequently performed employing principal axis factoring method of factor extraction.

Table 1: *Parallel Analysis: Eigenvalues of the Unrotated Factors for Study and Random Data*

	Eigenvalues	
Factor	Study Data	Random Data
1	**12.500**	**1.548**
2	**4.635**	**1.481**
3	1.218	1.435
4	1.117	1.362
5	0.998	1.292
6	0.908	1.274
7	0.684	1.264
8	0.659	1.185
9	0.626	1.161
10	0.578	1.134
11	0.535	1.091
12	0.516	1.046
13	0.487	1.030
14	0.451	1.007
15	0.397	0.998
16	0.378	0.955
17	0.363	0.925
18	0.339	0.890
19	0.317	0.879
20	0.299	0.867
21	0.290	0.832
22	0.273	0.796
23	0.265	0.783
24	0.233	0.768
25	0.222	0.745
26	0.199	0.705
27	0.180	0.687
28	0.169	0.649
29	0.085	0.623
30	0.079	0.589

Two rotation methods were originally considered for this study: orthogonal and oblique rotations. An orthogonal rotation is deemed more appropriate if the factors are independent, while an oblique rotation is more suitable for factors that are related to each other (Norman & Streiner, 2008). Because all items included on the MARS-Brief presumably measure the same construct (math anxiety), an oblique promax rotation (Kappa = 4) was deemed a more appropriate rotation method. As it can be seen from the rotated factor pattern coefficient matrix

(Table 2), the oblique rotation yielded a simple solution regarding Factors I and II, which contained no factorially complex variables (variables that load strongly on two or more factors). The structure coefficients, corresponding to the correlations between the measured variables and the extracted factors, are also given in the table. Further, it needs to be noted that "high" pattern coefficients were considered to be the ones with values higher than 0.4. Therefore, the variables with pattern coefficients of 0.4 and below were not considered to be the measures of the corresponding factors.

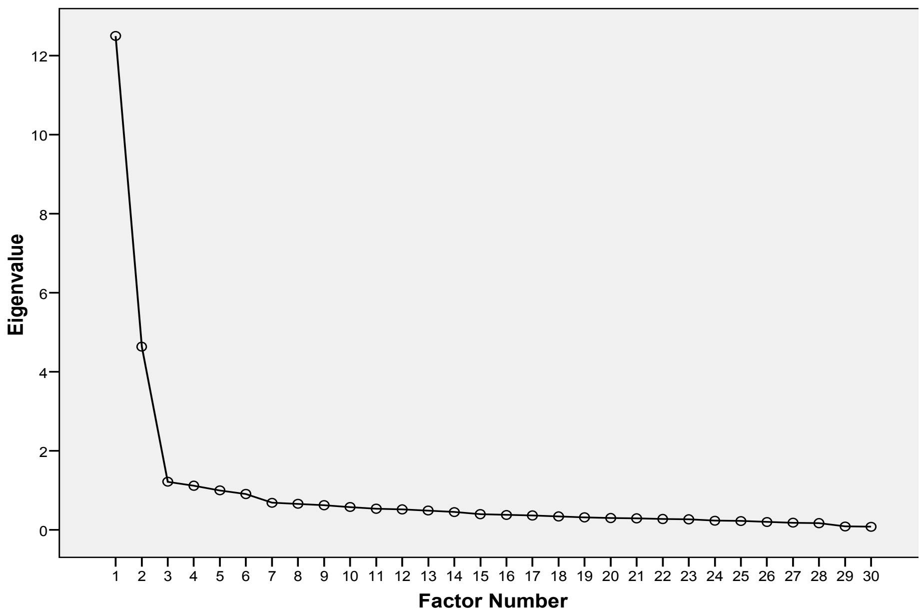

Figure 1. The scree plot of factors. There are two eigenvalues before the scree, implying that two factors should be extracted in the factor analysis.

Of the 30 measured variables, 15 represented Factor I, which accounted for 40.186% of the variance of the MARS-Brief scores (Eigenvalue = 12.056). This factor, labeled Numerical Anxiety, pertained to a manipulation of numbers in ordinary situations. The instrument items measuring Numerical Anxiety are given in Table 3. The other 15 variables, given in Table 4, represented Factor II. Labeled Math Test Anxiety, this factor was related to the assessment of one's math ability in academic settings, and accounted for 14.134% of the total variance (Eigenvalue = 4.240). As previously mentioned, due to their nature, a certain level of correlation between Factors I and II was expected (hence the choice of an oblique rotation). This was confirmed by computing the factor correlation coefficient between Factor I and Factor II of 0.453.

Table 2: *Rotated Factor Pattern and Structure Coefficients*

Variable	Factor I Coefficients		Factor II Coefficients	
	Pattern	Structure	Pattern	Structure
1	-0.145	0.237	**0.843**	0.777
2	0.061	0.399	**0.746**	0.774
3	-0.136	0.265	**0.885**	0.824
4	-0.192	0.215	**0.899**	0.812
5	-0.157	0.220	**0.832**	0.761
6	0.135	0.350	**0.474**	0.536
7	-0.004	0.269	**0.602**	0.600
8	0.106	0.384	**0.613**	0.661
9	-0.053	0.287	**0.751**	0.727
10	0.150	0.447	**0.655**	0.723
11	0.153	0.420	**0.589**	0.658
12	0.095	0.448	**0.780**	0.823
13	0.326	0.526	**0.441**	0.589
14	0.085	0.361	**0.609**	0.648
15	0.265	0.523	**0.568**	0.689
16	**0.505**	0.590	0.188	0.416
17	**0.785**	0.756	-0.064	0.291
18	**0.861**	0.770	-0.202	0.189
19	**0.722**	0.733	0.023	0.351
20	**0.730**	0.743	0.029	0.359
21	**0.838**	0.815	-0.051	0.329
22	**0.563**	0.650	0.191	0.446
23	**0.751**	0.760	0.020	0.360
24	**0.536**	0.591	0.121	0.364
25	**0.495**	0.585	0.198	0.423
26	**0.685**	0.743	0.127	0.438
27	**0.816**	0.764	-0.116	0.254
28	**0.735**	0.768	0.074	0.407
29	**0.929**	0.874	-0.123	0.298
30	**0.893**	0.875	-0.040	0.365

Table 3: *MARS Brief Items Representing Factor I (Numerical Anxiety)*

Pattern Coefficients	Item	Description
0.929	29	Being given a set of subtraction problems to solve.
0.893	30	Being given a set of multiplication problems to solve.
0.861	18	Reading a cash register receipt after your purchase.
0.838	21	Being given a set of numerical problems involving addition to solve on paper.
0.816	27	Watching someone work with a calculator.
0.785	17	Adding up 976+777 on paper.
0.751	23	Totaling up a dinner bill that you think overcharged you.
0.735	28	Being given a set of division problems to solve.
0.730	20	Figuring out your monthly budget.
0.722	19	Figuring the sales tax on a purchase that costs more than $1.00.
0.685	26	Totaling up the dues received and the expenses of a club you belong to.
0.563	22	Having someone watch you as you total up a column of figures.
0.536	24	Being responsible for collecting dues for an organization and keeping track of the amount.
0.505	16	Dividing a five digit number by a two digit number in private with pencil and paper.
0.495	25	Studying for a driver's license test and memorizing the figures involved, such as the distances it takes to stop a car going at different speeds.

Table 4: *MARS Brief Items Representing Factor II (Math Test Anxiety)*

Pattern Coefficients	Item	Description
0.899	4	Thinking about an upcoming math test one hour before.
0.885	3	Thinking about an upcoming math test one day before.
0.843	1	Taking an examination (final) in a math course.
0.832	5	Thinking about an upcoming math test five minutes before.
0.780	12	Taking an examination (quiz) in a math course.
0.751	9	Being given a "pop" quiz in a math class.
0.746	2	Thinking about an upcoming math test one week before.
0.655	10	Studying for a math test.
0.613	8	Realizing that you have to take a certain number of math classes to fulfill the requirements in your major.
0.609	14	Being given a homework assignment of many difficult problems which is due the next class meeting.
0.602	7	Receiving your final math grade in the mail.
0.589	11	Taking the math section of a college entrance exam.
0.568	15	Getting ready to study for a math test.
0.474	6	Waiting to get a math test returned in which you expected to do well.
0.441	13	Picking up the math text book to begin working on a homework assignment.

Major Dimensions of MARS-Brief

The mean MARS-Brief score was 65.8 and the standard deviation was 20.7. Based on the highest eigenvalues, the two major subscales on the MARS-Brief were Numerical Anxiety and Math Test Anxiety. In order to determine which dimension of math anxiety dominated the scores on the MARS-Brief, certain descriptive statistics were computed. It was found that the mean score on the Numerical Anxiety subscale was 23.588 and on Math Test Anxiety, the mean score was 42.207 with standard deviations of 10.303 and 13.527 respectively. As previously mentioned, the maximum possible score on the MARS-Brief was 150, while the maximum scores on the Numerical Anxiety and the Math Test Anxiety subscales were 75.

The means on the two subscales were compared using a dependent t-test. Results from a dependent t-test indicated that the difference in means was statistically significant, $t(472) = 33.118$, $p < .001$. Although the items on the MARS-Brief employed the Likert scale, and therefore the collected data was ordinal, in order to understand the nature of the participants' responses, we treated it as interval data. For this purpose, we computed an 'average score per item', which was defined as a ratio of average score and total number of items on the scale. The average score per item on the Numerical Anxiety subscale was 1.573 (SD = 0.687), while on the Math Test Anxiety subscale it was 2.813 (SD = 0.902).

The basis of the entire research on math anxiety is the belief that math anxiety is prevalent among college students. While certain studies provided a fair amount of support for this statement, others raised concerns regarding this assertion, as discussed below. An important indicator of math anxiety is a score on a scale measuring this construct. If MARS (or any MARS based instrument) is a well constructed instrument made up of only relevant items important to assessing the presence of this condition in subjects, then participants with high levels of math anxiety should be responding to the majority of items in such a way as to lead to their having high scores. The scores should be high not only on the overall instrument, but also on the subscales which presumably tap into major dimensions of the measured construct. The range of low fractional scores on the MARS and its modified versions reported in the literature, as well as the current study, can be interpreted to cast a shadow of doubt regarding the actual existence of this condition among the participating samples (assuming that MARS remains a relevant instrument for measuring this construct).

Furthermore, the presence of various instruments that may not be tapping into the same dimensions of math anxiety is not as alarming as the fact that not all instruments recognize numerical anxiety as an integral part of this construct (Kazelskis, 1998). The low scores on the numerical anxiety subscales, including the ones presented in this study, question the adequacy of the MARS based instruments in assessing this dimension, which is believed to be the integral part of math anxiety.

While in some studies, Math Test Anxiety (also referred to as Math Evaluation Anxiety) seems to be dominating the scores on the MARS and MARS based instruments (Alexander & Cobb, 1989; Resnick et al., 1982; Rounds & Hendel, 1980), others recognize a different factor, in most cases Numerical Anxiety, as the dominant one (Brush, 1978; Plake & Parker, 1982). One may argue that this lack of agreement can be explained by a difference in instruments used in the studies. However, most studies employed the MARS, and yet differences in the factor analyses findings were still present. This suggests that scores on the MARS may be impacted by certain factors independent of the instrument; the factors that are most likely related to a sample or some other outside influences.

As mentioned previously, a review of the literature on the dimensionality of math anxiety as measured by the MARS and MARS based instruments revealed a lack of inquiry on the part of the studies (reported in the literature) into a relationship between the identified factors and scores on the corresponding subscales. One may expect that the factor dominating the instrument (factor accounting for the largest part of the variance) would coincide with the subscale that has the highest score. For example, Math Test Anxiety was recognized as the first of three factors extracted as a result of factor analysis[2] performed by Alexander and Martray (1989). That factor had the highest average score per item (2.73) compared to the other two. However, the results of a few other studies that reported the scores on their subscales contradict this finding. The second factor (labeled Evaluation Anxiety) identified in a factor analysis of the MARS (Brush, 1978) had a higher average score per item (ranging from 1.93 to 2.72) than the first factor (labeled Problem-Solving Anxiety) with average scores per item between 1.33 and 1.66. Similar results are reported by Morris et al. (1978). Of three factors extracted in that study, the second one, Math Test Anxiety, had the highest average score per item of 2.84 (student enrolled in a math course) and 3.14 (students enrolled in a psychology course). Evaluation Anxiety was also identified as the first of three factors extracted by factor analysis of the MARS by Resnick et al. (1982). This factor, however, had a lower average score per item than the second factor, Social Responsibility Anxiety. Reports of scores on the subscales identified by other researchers would have aided in determining any significant trends between the factors and the subscale scores; unfortunately, this type of data is scarce in the existing literature. Finally, inconsistencies in results of factor analyses of scores on MARS based instruments may also be contributed to the use of various methods for determining the number of factors to be extracted, different extraction, and rotation methods.

Discussion

The factor analysis in the present study identified two dimensions underlying math anxiety as measured by the MARS-Brief. The two factors that had the most salient items coincide with factors identified by Suinn and Winston (2003) who factor analyzed the same instrument. In their study, Math Test Anxiety was identified as the dominant dimension of the MARS-Brief with a significantly larger eigenvalue and percentage of variance than the ones corresponding to Numerical Anxiety. They did not, however, report scores on these subscales which prevented us from determining which dimension dominated the scores on MARS-Brief and compare it to the current results.

The factor analysis findings in this study suggest that the anxiety related to manipulation of numbers in everyday settings should be more prevalent than the one stemming from evaluation of one's math ability (as indicated by a higher eigenvalue and percentage of total variance corresponding to Numerical Anxiety). However, significantly different from the mean score on the Numerical Anxiety, the Math Test Anxiety mean score indicated that the participants exhibited moderate anxiety when faced with an evaluation of a math task (item mean = 2.813), while they experienced no, or at most very little anxiety related to everyday manipulation of numbers (item mean = 1.573). That the scores were significantly higher on the evaluation subscale than on the numerical one suggests that college students' anxiety comes, not necessarily from facing a mathematical task, but rather from being evaluated on one. Therefore, although the Numerical Anxiety factor dominated the instrument, the Math Test Anxiety seemed to dominate the scores on the instrument. This would imply that Math Test Anxiety is a more prevalent dimension of math anxiety.

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[2] It needs to be noted that the order of extraction of factors corresponds to the ranking of their eigenvalues. For example, if a certain factor is extracted first, then its eigenvalue is the largest one of all, and this factor dominates the instrument.

The low scores on the Numerical Anxiety subscale, but significantly higher scores on the Math Test Anxiety subscale warrant a further inquiry into whether this is due to a decrease in the usefulness of MARS based instruments in measuring math anxiety in 21^{st} century college students, or is due to the need for more thorough investigation into the nature of math anxiety and its principal dimensions. For example, if we consider responses on both the Numerical Anxiety and Math Test Anxiety subscales of at least '3', (corresponding to 'a fair amount') to be indicators of moderate to high math anxiety, we see that only 31 participants (or 6.55%) seem to be experiencing at least moderate levels of math anxiety, as measured by this instrument. This is consistent with Rounds and Hendel's (1980) observation that at most 6% of the participants scored high on both MARS derived factor scales (Mathematics Test Anxiety and Numerical Anxiety). Therefore, the focus should be on investigating the relationship between math anxiety and test anxiety, and trying to determine if a high correlation between the two indicates a strong connection between the two distinct constructs, or just that the two are parts of a larger whole. The case of the former would supplement the need for reevaluation of MARS based instruments and their ability to tap into all aspects of math anxiety, and efficiently distinguish this construct from test anxiety.

Summary

While the current study recognized two major dimensions of math anxiety that were consistent with the findings in the literature, the results also indicated that the dimension which seemed to be dominating the instrument (Numerical Anxiety), did not necessarily dominate the measured construct. Also concerning were relatively low scores on the math anxiety instrument, and especially low scores on the numerical anxiety subscale. These low mean scores can be interpreted as contradictory to claims of the prevalence of math anxiety on college campuses. However, a lack of high scores on math anxiety scales as well as numerical anxiety subscale when using MARS should not necessarily be interpreted to suggest that this condition is not very prominent among college student populations. Since many college professionals report anecdotal evidence that students are experiencing significant levels of math anxiety, it may be more likely that the instruments used to assess this condition are no longer valid or that they may not encompass all the aspects of what has proven to be a very complex, multidimensional construct.

The current inquiry revealed areas that warrant further research. These include a development of an instrument measuring math anxiety that will potentially tap into all dimensions of math anxiety experienced by college population of our time. This requires a detailed, in-depth qualitative study designed to identify the major dimensions of this construct, followed by a rigorous quantitative study created to provide strong psychometric data pertaining to the scores of such instrument. To fully understand what math anxiety entails, it may be necessary to take this investigation out of the bound of academia where students' responses on scales measuring this phenomenon are possibly influenced by feelings of anxiousness related to constructs other than math anxiety. Furthermore, the need for an instrument that will measure not just the commonly accepted dimensions of math anxiety, but also the ones presumably not tapped into by the MARS, may be critical to fully understanding this important construct.

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