MATHEMATICS ANXIETY: SCAFFOLDING A NEW CONSTRUCT MODEL

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Over the years there has been a lack of conceptual clarity and explicit definition of the construct mathematics anxiety. This paper describes a process of building, refining, and validating a construct model of mathematics anxiety using a Rasch Rating Scale.

Background

The purpose for the research project was the growing need to understand in better and clearer ways the construct *mathematics anxiety*. This need was identified from the meta-analysis undertaken by Ma and Kishor (1997) where they noted the confusion caused for many people from the fact that researchers rarely offered explicit definitions of their construct or borrowed instruments from other disciplines, such as psychology without adapting them specifically for use in mathematics education. A further motivation for the project was to understand the manifestation of mathematics anxiety in different situations, at different times, and for different people. Such an understanding is important for people concerned with mathematics education in all its forms.

Early work on mathematics anxiety is associated with Richardson and Suinn (1972) and their development of the *Mathematics Anxiety Rating Scale* (MARS). They also offered a straightforward definition for mathematics anxiety stating that it involved "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (p. 551). Over the years further scales have been devised, for example, the *Revised Mathematical Anxiety Rating Scale* noted by Baloglu and Kocak (2006). The apparent simplicity of the original 1972 definition is questioned as mathematics anxiety has been shown by some researchers to involve multiple dimensions (Kazelskis, 1998) whereas others have confirmed it as having a uni-dimensional structure (Beasley, Long & Natali, 2001). These uncertainties and contradictions on how mathematics anxiety is conceptualised have resulted in no commonly accepted construct model and the need to refine measures.

Experiencing mathematics anxiety

Mathematics anxiety is experienced for many people in a range of ways. Psychological indicators of mathematics anxiety include such things as feelings of tension, fear and apprehension, low self confidence, a negative mind set towards mathematics learning, feeling threatened, failing to reach potential, and a temporary reduction in working memory (Ashcraft & Kirk, 2001; D'Ailly & Bergering, 1992; Jain & Dowson, 2009; Perry, 2004; Richardson & Suinn, 1972; Zohar, 1998.) It is physiologically exhibited by sweaty palms, a feeling of nausea, difficulty with breathing, and for some people heart palpitations (Malinski, Ross, Pannells & McJunkin, 2006; Perry, 2004). Additionally, it interferes with calculating and the solving of mathematical problems in academic, private and social environments (Richardson & Suinn, 1972; Suinn, Taylor & Edwards, 1988). Within a classroom or school environment it is most often associated with children undertaking learning in mathematics, however it is not restricted to children. Some teachers have reported nervousness and lack of confidence when confronted with teaching aspects of mathematics (Malinsky, Ross, Pannells, & McJunkin, 2006). As noted earlier it is a common occurrence in work and everyday life. Often it is seen where people avoid situations and even careers that require the use of even basic mathematical skills (Hopko, 2003).

Many research projects have investigated and tried to understand the causes of mathematical anxiety with the intention of being able to improve attitudinal and cognitive aspects of mathematics learning (Jain & Dowson, 2009; Perry, 2004). The sources of mathematics anxiety are varied, interrelated, and also inconsistent in their effects, for example some studies have noted an influence of gender while others have failed to substantiate this influence (Baloglu & Kocak, 2006). Others, (Furner & Berman, 2003; Jackson & Leffingwell, 1999) have reported that age is also a factor in school student perceptions of mathematical anxiety. One such possible cause of mathematics anxiety, that of teacher behaviour, differed between elementary and high school levels. However, causes of mathematical anxiety may be broadly categorised as attributes of the children, the family, the teacher and instruction, and the nature of mathematics itself.

The construct of mathematics anxiety

While it may be possible and useful to describe the factors influencing mathematics anxiety and also how it is manifested in everyday life, this is insufficient for defining precisely a psychological construct or latent trait. A construct model is normally used to specify the crucial aspects of a latent trait. Wolfe and Smith (2007) noted the following functions of a construct model. It can describe:

- The internal structure of the construct;
- Its relationship to other constructs;
- The incumbent developmental assumptions—levels of proficiency; and
- The incumbent cognitive processing assumptions—cognitive activities and states.

In the following sections these four functions of a construct model will be used as a theoretical framework to review the literature on mathematics anxiety with a view to clarify the construct.

The internal structure of the mathematics anxiety construct

This aspect of construct definition rests on two issues, namely differentiating between mathematics anxiety and test anxiety, and the dimensionality of mathematics anxiety. The data from measures of mathematics anxiety and the measures of test anxiety are often correlated to suggest a similarity between the two anxieties. Others (Kazelskis, et. al. 2000) interpreted mathematics anxiety as a component of test anxiety. However, the extent of correlation between the data is low and often dependent on the measure used. Analysis of data from different anxiety measures provides evidence to suggest that mathematics anxiety is at times multi-dimensional (Baloglu & Zelhart, 2007) while at others it is uni-dimensional (Beasley, Long & Natali, 2001). All the multi-dimensional measures of mathematics anxiety include a 'test anxiety' dimension. There is also little evidence to suggest a single higher order mathematics anxiety construct.

Relationship of mathematics anxiety to other constructs

Measures of mathematics anxiety negatively correlate with measures of mathematical ability, particularly when this is assessed in test situations. D'Ailly and Beregering (1992) noted the small yet significant correlations of mathematics anxiety and mathematics avoidance. Jain and Dowson (2009) used a Motivated Strategies for Learning Questionnaire and noted a direct relationship for self-regulation and self-efficacy with an inverse relationship between self-efficacy and mathematics anxiety. Earlier work by Wigfield and Meece (1988) identified correlations between mathematics anxiety and measures of mathematical ability perceptions, mathematics task demands, mathematics interest, and mathematics performance. These positive and negative associations substantiate theorised similarities and differences between mathematics anxiety and related constructs. These will provide external reference points for the construct model.

Developmental assumptions

It is recognised that latent traits such as cognitive abilities have a developmental aspect. This aspect often has an assumption of a hierarchical development to acknowledge changes and growth over time. The literature on mathematics anxiety is limited in examples of a developmental feature. Prieto and Delgado (2007), however, developed such a model for mathematics anxiety with 'experiencing nausea' indicating a higher level of anxiety than 'my mind goes blank'. Any model that attempts to map the development of anxiety over time must collect data on the same qualities rather than on different qualities.

Cognitive processing assumptions

Cognitive processes and cognitive states govern psychological manifestations of a latent trait, such as mathematics anxiety. While these aspects of the construct are not directly observable, assumptions can be made in the model to note confirmatory evidence that will come forward.

The objective measurement of mathematics anxiety

The following section will explore the idea of applying Modern Measurement Theory in the form of the Rasch model with its potential to resolve some of the difficulty in explaining and operationally defining and building an objective measure of the construct mathematics anxiety.

A construct model of mathematics anxiety

In the following model the horizontal dimension shows three types of anxiety derived from the literature on mathematics anxiety—anxiety when being taught mathematics, anxiety when mathematics knowledge is being assessed, and anxiety when mathematics is required to be applied in situations beyond the classroom. The order of presentation in the model is arbitrary and it is acknowledged that there may be relations between the three. The model suggests eight potential areas of anxiety.

The vertical dimension illustrates levels of anxiety. Extreme anxiety is indicated by somatic (physical and body) factors such as heart palpitations. Cognitive (mental processes) factors indicate high anxiety; such factors here are confusion, and one's mind going blank. Low anxiety factors are generally attitudinal, shown by lack of confidence. It is also suggested that the indicators are cumulative, that is a person showing extreme anxiety will also exhibit those of low anxiety. These lower indicators could be less obvious due to the over-shadowing of the extreme indicator.

Table 1. Situational model of mathematics anxiety.

		Situational types of mathematics anxiety							
		Instruction			Assessment		Application		
Level	**Domains**	Independent work	Group work	Working in a class group	Formal - examinations and tests	Informal - quizzes and worksheets	Other subjects	Home	Work
Extreme anxiety	Somatic indicators								
	Cognitive indicators								
Low anxiety	Attitudinal indicators								

Testing the model

A small study was planned to test the assumptions present in the *Situational model of mathematics anxiety* (Table 1). Specifically, it considered three issues:

1. Can a linear scale of mathematics anxiety be constructed?
2. Are the distributions of scores for different types of mathematics anxiety different?
3. Is the theorised order of the anxiety indicators consistent with the ordering of the anxiety scores?

Research methods

Two forms of questionnaire were designed. One sought information on anxiety when working on mathematics in a class (Form A), and the other on anxiety on completing a test on mathematics (Form B). Both forms comprised the same items in the same order. The items were grouped under three sub-headings of attitudinal (6 items), cognitive (9 items), and somatic (6 items). The larger number of cognitive indicators was included to make the scale more sensitive to students with 'average' anxiety.

Table 2. Questionnaire items.

Item label	Item number	Item
Som 1	14	I feel uncomfortable
Som 2	18	I shake or tremble
Som 3	17	I have sweaty palms
Som 4	16	I have difficulty breathing
Som 5	19	My heart beats more quickly
Som 6	21	My mouth becomes dry
Cog 1	7	I am worried about others thinking I am stupid
Cog 2	13	I feel threatened
Cog 3	1	I am aware of previous failures
Cog 4	9	I can't think clearly
Cog 5	15	I forget things I normally know
Cog 6	3	I am frustrated
Cog 7	2	I am not in control
Cog 8	5	I am confused
Cog 9	20	My mind goes blank
Att 1	8	I am worried about what I am expected to do
Att 2	12	I feel like running away
Att 3	10	I don't want to be doing this
Att 4	11	I expect to have difficulty doing what is required
Att 5	4	I am not confident I can do what is required
Att 6	6	I am scared about what I have to do

A scoring model describes how qualitatively different observed responses are translated into numerical codes. The scoring model selected for this study used four response categories on a Likert-type scale using 1 for strongly agree to 4 for strongly disagree. Scores were reversed for data entry and missing data were scored 9. Data were then placed into a scaling model so that "… ordinal codes [could be] combined and mapped onto a continuum that represents measurable quantities of the target construct" (Wolfe & Smith, 2007, p.108). The Rasch Rating Scale Model and the computer program RUMM2020 were used for this purpose (Andrich, Sheridan, Lyne & Luo, 2007).

Participants in the study were 50 (27 female and 23 male) children from seven Perth metropolitan primary schools. The children were in Years 5 to 7. They completed both forms of the questionnaire.

Table 3. Sample details.

School	1	2	3	4	5	6	7	Total
Females	10	4	2	3	1	4	3	27
Males	6	2	4	2	3	4	2	23
Total	16	6	6	5	4	8	5	50

Results

Data from the 100 questionnaires were entered into RUMM2020 and a variety of analyses were undertaken. First, the use of the response categories was examined by estimating the thresholds between adjacent response categories. A threshold is a student anxiety score for which there is an equal probability of selecting either of the adjacent categories. Items Att 2 and Cog 5 elicited data with disordered thresholds and these data were removed prior to subsequent analyses.

Next, data fit was examined. When data fit the Rasch model, the observed scores for an item should be similar to the score predicted by the model for persons of similar ability. It was noted that students with low anxiety scores responded more affirmatively than expected while those with high anxiety scores responded less affirmatively than expected. The residual, the difference between the observed score for an item and the score predicted by the model, was high (3.25) for item Att 6.

A Chi Square is estimated to show the interaction between an item and the trait. A low Chi Square probability value is due to poor item trait interaction. Six items were identified with high residual (>2.5) and/or low Chi Square probability values after the Bonferroni adjustment. Data from these items were removed prior to the final analysis.

The data from the remaining 13 items fitted the Rasch Rating Scale model well so it was possible to compare student mathematics anxiety scores and item difficulty. Plotting item difficulty locations and student anxiety scores on the same scale showed students tended to be reluctant in their affirmation of the anxiety indicators. A Principal Components Analysis of residuals after the Rasch measure was extracted provided evidence of multidimensionality.

Data for test anxiety and for classroom anxiety were compared with mean scores and standard deviations were similar, suggesting minimal sample-wide differences between student reports of mathematics anxiety in the two situations. However, when the pairing of scores for individual students was compared, students reporting low test anxiety generally reported comparatively high classroom anxiety. The converse was also apparent. Anxiety experiences in relation to the test and classroom contexts, it is suggested, depend on the individual student.

The difficulty the students experienced in affirming the respective items were estimated as item difficulty logits. From the three categories of indicators it was noted that one group were not more difficult to affirm than the others. It was also noted from analysis of the data on the separate forms that the item location sequences were similar.

Discussion

A model that builds on the original model (Table 1) developed from the literature search and pays attention to findings from the application of Modern Measurement Theory in the pilot study is illustrated in Table 4 (over).

Data from both forms of the instrument (test and classroom) fitted the Rasch model to provide evidence of a trait that is manifest in both situations. They are likely to be manifestations of the same construct and can be defined by the same indicators. In the original construct model there was an assumption of a cumulative relationship between the general indicators, that is some were seen as more difficult than others. This, it is suggested, is not the case and that high anxiety, as well as low anxiety, is indicated by a combination of attitudinal, cognitive, and somatic indicators.

Table 4. Model of mathematics anxiety.

Dominant trait model of mathematics anxiety				
Level of anxiety	Indicators	Attitudinal	Cognitive	Somatic
High anxiety		Scared about what s/he has to do	Worried about others thinking s/he is stupid	Having difficulty breathing
Moderate anxiety		Not wanting to be doing what has to be done	Mind going blank	Heart beats more quickly
Low anxiety		Expecting to have difficulty doing what is required	Being confused	Feeling uncomfortable
Potential applications	*In-class instruction:* Independent work, group work, or whole class *In-class assessment:* Formal exam or tests, informal quizzes *Out-of-class applications:* Other subjects, at home, at work or socially			

The model also acknowledges that mathematics anxiety can arise in any situation in which mathematical skills and knowledge are required. The indicators of mathematical anxiety are common to all situations and the relative 'severity' of the indicators is also assumed not to vary across situations. Implicit in this model is the notion that this construct will vary in degree between individuals in different situations.

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