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Measuring Mathematics Engagement Anxiety

a MARS-style instrument for an active and interactive classroom

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Abstract We present a validation study of fifteen new math anxiety scale items designed to augment the widely-used Revised Mathematics Anxiety Scale (RMARS). While the RMARS and other standard instruments measure students' anxiety in response to computation, test situations, and math course activities such as buying a textbook or watching a lecture, the new items address students' anxiety in response to doing mathematics in an active and interactive classroom. With a survey sample of 132 future teachers enrolled at colleges and universities, we use exploratory and confirmatory factor analyses to groups the fifteen new items into three new dimensions of math anxiety: Problem-Solving Anxiety, Explanation Anxiety, and Explanation with Internal Doubt Anxiety. Further, Cronbach's alpha for the overall scale, as well as for each dimension individually, are all between 0.9 and .95, indicating internal consistency.

1 Introduction

Researchers have long been concerned with measuring math anxiety and its effects on math performance through emotional, physiological, or behavioral mechanisms (e.g., Novak & Tassell, 2017; Ashcraft & Moore, 2009; Ashcraft & Krause, 2007; Ashcraft, 2002; Ashcraft & Kirk, 2001; Hopko, Ashcraft, Gute, Ruggiero, & Lewis, 1998; Hembree, 1990). As mathematicians and college math instructors, our interest in math anxiety centers less on physiological and behavioral manifestations and more on the socio-cultural practice of doing mathematics in our classrooms. For example, *how does math anxiety affect students' ability to participate in our classrooms? And what can we do about it? How might students' math anxiety inform our assessment decisions? Which practices of doing mathematics induce anxiety in our students?* For

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students who are training to be teachers, *how does anxiety around math practices in our classrooms relate to the math practices they choose to implement (or not) in their own future classrooms?* To facilitate the study of these kinds of questions, our overall goal in this paper is to put forth additional, validated items for measuring math anxiety that further illuminate the multidimensionality of the construct and allow for more nuanced studies of its effects, particularly in a student-centered mathematics classroom. The items we developed are applicable to a broad range of undergraduate mathematics settings, and especially to pre-service teachers.

In 1972, the psychologists Richardson & Suinn defined math anxiety as

> a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations. (p. 551)

This definition was given alongside a 98-item inventory to measure the construct: the Mathematics Anxiety Rating Scale, or MARS. Currently, the most commonly used instruments for measuring math anxiety are revisions of this 1972 scale (Alexander & Martray, 1989; Ferguson, 1986; Plake & Parker, 1982; Resnick, Viehe, & Segal, 1982). These all consist of Likert-scale questions that ask respondents to rate their level of anxiety in various situations on a scale from 1 ("not at all") to 5 ("very much"). Using various versions of the MARS instrument, multiple studies have found the math anxiety construct to be multidimensional (see Table 1). While it is well-established what aspects of math anxiety the MARS-based inventories measure, an examination of the items shows that they fail to capture the full spectrum either of what it means to do "solve mathematical problems" or of mathematical "academic situations" students are likely to encounter today. As trained mathematicians and involved in post-secondary mathematics pedagogy, the authors feel particularly qualified to address this issue[1].

To demonstrate these disciplinary and pedagogical differences, Figure 1 presents some example items from an existing instrument—the Revised Mathematics Anxiety Rating Scale, or RMARS (Alexander & Martray, 1989)—in comparison to some of our newly proposed items. The RMARS items rely on assumptions that

MARS/RMARS Items

- Watching a teacher work an algebraic equation on the blackboard.
- Thinking about an upcoming math test one day before.
- Listening to a lecture in math class.
- Being given a set of division problems to solve.

New (MEARS) Items

- Being asked to solve a math problem when you are not sure which formulas to use.
- Being asked to further justify why your mathematical solution is correct to a classmate who is not yet convinced.
- Sharing your solution with a small group of classmates when you are not sure it is correct.

Fig. 1 Selected items from the (Revised) Mathematics Anxiety Rating Scale (R/MARS) and from the new Mathematics Engagement Anxiety Rating Scale (MEARS).

[1] To our knowledge, no mathematicians have been involved in the creation of any of the other instruments designed to measure math anxiety.

(a) mathematics as a discipline consists of rote computations and procedures, and (b) that a mathematics classroom is centered on lectures and exams. Our items, in contrast, attempt to add a richer picture of mathematics that includes (a') solving novel problems, including those for which you do not know where to start and (b') more diverse and progressive classroom situations, including giving mathematical justifications and explanations to peers.

In this paper, we first examine the definition of math anxiety (see especially §2.2), focusing on contemporary interpretations of "solving mathematical problems" and "academic situations". Based on this literature review and our own experiences teaching college mathematics, we propose additional items (see §3.1) to augment the existing most-used instrument for measuring math anxiety, the aforementioned RMARS. Our new 15-item inventory—the Mathematics Engagement Anxiety Rating Scale (MEARS)—was written with two constructs and five sub-constructs in mind. The two main constructs we intended to measure are *Problem Solving Anxiety* (a feeling of anxiety in response to encountering conceptually difficult or novel math problems, or from the length of problems), and *Explanation Anxiety* (a feeling of anxiety in anticipation of or response to explaining one's mathematical ideas to others). The central sections of the paper report a factor analysis and validation of these new items (see Methods and Results in §3 and §4), based on data from 132 pre-service teachers at colleges and universities. Exploratory and confirmatory factor analysis of this data grouped the 15 MEARS items into three factors: our original two constructs of Problem Solving Anxiety and Explanation Anxiety and, separately, Explanation with Internal Doubt Anxiety—originally designed as a sub-construct of Explanation Anxiety[2]. Further exploratory factor analyses show that these factors are distinct from those in the Revised Mathematics Anxiety Rating Scale (RMARS) instrument, and that they are also distinct from general anxiety as measured by the State-Trait Anxiety Inventory (STAI).

2 Literature Review

The bulk of this Literature Review (§2.2) is dedicated to digging deeper into two key phrases in the definition of math anxiety (see page 2)—"solving of mathematical problems" and "academic situations"—and how our understanding of these terms should inform the way we measure math anxiety. Before dissecting this definition, we start with an overview of how math anxiety has traditionally been measured and what dimensions of math anxiety have repeatedly been identified (§2.1). These two pieces—the dimensionality of math anxiety and a deeper look into the subtleties of its definition—frame the current study's addition of new dimensions to our understanding of math anxiety. Finally, since we piloted our new instrument on a very specific population—future elementary teachers—we outline some of the literature related to math anxiety in this special population and why it is of particular interest (§2.3).

[2] These sub-constructs are described in Section 3.1.