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Mathematics anxiety in young children: Concurrent and longitudinal associations with mathematical performance

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ABSTRACT

This study explored mathematics anxiety in a longitudinal sample of 113 children followed from second to third grade. We examined how mathematics anxiety related to different types of mathematical performance concurrently and longitudinally and whether the relations between mathematics anxiety and mathematical performance differed as a function of working memory. Concurrent analyses indicated that mathematics anxiety represents a unique source of individual differences in children's calculation skills and mathematical applications, but not in children's geometric reasoning. Furthermore, we found that higher levels of mathematics anxiety in second grade predicted lower gains in children's mathematical applications between second and third grade, but only for children with higher levels of working memory. Overall, our results indicate that mathematics anxiety is an important construct to consider when examining sources of individual differences in young children's mathematical performance. Furthermore, our findings suggest that mathematics anxiety may affect how some children use working memory resources to learn mathematical applications.

1. Introduction

Mathematics anxiety refers to feelings of tension or worry that interfere with mathematical performance in daily life and school settings (e.g., Richardson & Suinn, 1972; Wigfield & Meece, 1988). Mathematics anxiety has consistently been found to have an inverse relation with mathematical performance, with correlations estimated between −.27 and −.34 for children across the middle and high school grades (Hembree, 1990; Ma, 1999). The negative impacts of mathematics anxiety have far-reaching consequences: compared to their less anxious peers, mathematically anxious students enjoy mathematics less, have lower perceptions of their mathematical abilities, and do not see the value of mathematics in everyday life (Ashcraft, Krause, & Hopko, 2007; Ashcraft & Moore, 2009; Hembree, 1990). Indeed, mathematically anxious students participate less in mathematics classes in middle school and steer away from mathematical majors (see Hembree, 1990; Meece, Wigfield, & Eccles, 1990). These patterns are particularly troubling given that mathematical proficiency is becoming increasingly important for full economic opportunity and meaningful participation in society (e.g., Moses & Cobb, 2001; Peterson, Woessmann, Hanushek, & Lastra-Anadón, 2011).

Although much has been learned about the development of mathematics anxiety, the vast majority of this extant research has focused on cross-sectional samples of fourth grade through college students (e.g., Baloğlu & Koçak, 2006; Birgin, Baloğlu, Catlıoğlu, & Gürbüz, 2010; Capraro, Capraro, & Henson, 2001; Newstead, 1998; Suinn, Taylor, & Edwards, 1988). For instance, from studies with older children and adults, we have learned that mathematics anxiety is a multi-dimensional construct, is distinct from both general and test anxiety, is not related to general intelligence, and appears to be a cause rather than simply a correlate of performance deficits (Ashcraft et al., 2007; Hembree, 1990; Ma, 1999). A major unresolved issue in the field concerns the early development of mathematics anxiety and whether there is practical utility in identifying mathematics anxiety-related behaviors in young children.

Although a few studies have begun to investigate mathematics anxiety in young children (i.e., Harari, Vukovic, & Bailey, in press; Krinzinger, Kaufmann, & Willmes, 2009; Ramirez, Gunderson, Levine, & Beilock, in press), there are mixed findings in this still new literature. For instance, Krinzinger et al. (2009) found that some first through third graders report mathematics anxiety-related characteristics—primarily worry—but this mathematics anxiety does not appear to relate to mathematical performance. By contrast, a study by Harari et al. (in press) suggests that other aspects of mathematics anxiety besides worry are indeed negatively related to mathematical performance in first graders. Finally, a study by Ramirez et al. (in press) suggests that mathematics anxiety in first and second graders may affect only those children with

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higher levels of working memory. Thus, the nature of mathematics anxiety in young children and its relation to mathematical performance—including over time—remains unspecified. Building on this research, the current study investigated the impact of mathematics anxiety on multiple mathematical outcomes, both concurrently and longitudinally, as well as examined whether this relation differed as a function of working memory.

1.1. The nature and assessment of mathematics anxiety

Considered a performance-based anxiety similar to social phobia and test anxiety, mathematics anxiety involves physiological arousal and negative cognitions both in the immediate context of a performance-based setting (e.g., math class) or in anticipation of having to perform (e.g., being called on during math class) and the potential for negative evaluation by either teachers or peers (Ashcraft et al., 2007; Hopko, McNeil, Zvolensky, & Eifert, 2001). Although the etiology of mathematics anxiety is unclear, the conception in the field is that mathematics anxiety results primarily from cumulative negative experiences in school as students encounter increasingly challenging mathematical material (e.g., Ashcraft et al., 2007; Beilock, Gunderson, Ramirez, & Levine, 2010; Geist, 2010). Indeed, in a meta-analysis, Hembree (1990) synthesized cross-sectional evidence suggesting that levels of mathematics anxiety increase from fifth grade throughout middle school, reaching peak levels in ninth and tenth grade, followed by a leveling off during later high school and college. This theory raises questions about whether young children who have had fewer experiences with mathematics by virtue of their age can experience the detrimental effects of mathematics anxiety. There is growing evidence that simple numerical tasks, such as counting and magnitude judgment, elicit mathematics anxiety in adults (Maloney, Ansari, & Fugelsang, 2011; Maloney, Risko, Ansari, & Fugelsang, 2010), suggesting that mathematics anxiety may have roots in early numerical abilities. Hembree's meta-analysis did not include studies of children younger than fifth grade because such studies did not exist at the time. Understanding the characteristics of mathematics anxiety in young children will therefore inform theoretical models about the nature, etiology, and treatment of mathematics anxiety.

Mathematics anxiety tends to be conceptualized—and subsequently operationalized—in one of two ways. The first considers mathematics anxiety as including two related aspects: numerical anxiety—the anxiety involved in using mathematics in ordinary life and academic situations; and mathematics test anxiety—the anxiety related to testing and evaluation in mathematics. The Mathematics Anxiety Rating Scale (MARS; Richardson & Suinn, 1972) is the prototype for examining numerical and test anxiety. Developed for use with adults, the MARS is a 98-item scale composed of brief descriptions of specific mathematical situations that may simulate anxiety in everyday situations (e.g., working on an income tax form) and academic test situations. Respondents rank each item on a 5-point scale ranging from "not at all anxious" to "very anxious," with higher scores indicating greater anxiety. The original MARS has been adapted to include brief versions for use with adults (Suinn, 2003), adolescents in 7th–12th grade (Suinn & Edwards, 1982), and elementary children in fourth to sixth grade (Suinn et al., 1988). Across studies, the MARS and its descendants have been shown to be psychometrically sound across sex, grade, and ethnicity (for reviews see Ashcraft et al., 2007; Hembree, 1990; Ma, 1999). The MARS has informed the development of more recent measures of mathematics anxiety (e.g., Hopko, Mahadevan, Bare, & Hunt, 2003), and has been the basis for designing measures to assess mathematics anxiety in children below fourth grade in a few cases (e.g., Gierl & Bisanz, 1995; Ramirez et al., in press; Young, Wu, & Menon, 2012).

The second conceptualization considers mathematics anxiety as including the same aspects as general anxiety, namely, worry (i.e., a cognitive component including concerns with doing well in mathematics) and negative reactions (i.e., an affective component including feelings of fear, dread, nervousness, and unpleasant physiological reactions). Although not used in research as frequently as the MARS series, some measures have been developed to assess mathematics specific negative affect and worry, including the Math Anxiety Questionnaire (MAQ; Wigfield & Meece, 1988), the Fennema–Sherman Mathematics Attitudes Scales (Fennema & Sherman, 1976), and the Mathematics Anxiety Scale (Betz, 1978). Mathematics specific negative affect and worry have been examined in individuals from 6th through 12th grade both in the United States (e.g., Bai, Wang, Pan, & Frey, 2009; Ganley & Vasilyeva, 2011; Hoffman, 2010; Mulhern & Rae, 1998; Wigfield & Meece, 1988), as well as in international samples including China and Taiwan (Ho et al., 2000), Turkey (Birgin et al., 2010), and Germany (Krinzinger et al., 2009), providing a strong basis for considering affective and cognitive aspects in the assessment of mathematics anxiety in young children.

The biggest challenge with exploring mathematics anxiety in young children is that currently existing measures are designed for children at or above the fourth grade, while capturing some but not all relevant dimensions. Correspondingly, researchers studying mathematics anxiety in young children have begun to devise exploratory measures with mixed success. In one of the first studies conducted with young children, Krinzinger et al. (2009) examined the relation between mathematics anxiety and mathematical performance with a sample of German children followed from first through third grade. The authors devised a scale in which children were asked to consider their attitudes and emotions pertaining to seven different mathematics-related situations: mathematics in general, written calculations, mental calculations, easy calculations, difficult calculations, mathematics homework, and understanding during mathematics instruction. Children answered four different types of questions for each situation ("*How good are you at: mathematics in general/written calculations/etc*?" "*How much do you like: mathematics in general/written calculations/etc*?" "*How happy or unhappy are you if you have problems with: mathematics in general/written calculations/etc*?" "*How worried are you if you have problems with mathematics in general/written calculations/etc?*"). Children marked their response to each item on a 5-point scale, with different response options for each question type: check marks and crosses for "how good are you" questions; wasps and candies for "how much do you like" questions; happy and unhappy faces for "how happy or unhappy" questions; and worried and relaxed faces for "how worried" questions.

The authors found evidence for two factors in their scale: general mathematics-related attitudes ("how good are you" and "how much do you like" questions) and negative emotions and anxiety ("how happy or unhappy" and "how worried" questions) (Krinzinger et al., 2009). Although the scales were reliable (Cronbach's alpha reported between .83 and .91), neither factor was statistically related to mathematical performance—specifically calculation skills—indicating that mathematics anxiety in young children may not be related to mathematical performance, but also perhaps that the scale was not a comprehensive assessment of mathematics anxiety in young children. Krinzinger et al. (2009) speculated that their null results reflected a methodological limitation in their scale. Specifically, the authors suggested that the wording of their items was too indirect and hypothesized that physiological reactions such as high pulse or avoidance behavior might be better than assessing the cognitive aspect of mathematics anxiety.

Building on the findings of Krinzinger et al. (2009), we extended the assessment of mathematics anxiety in young children to include not only worry, but also negative reactions and numerical