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Developmental trajectories of math anxiety during adolescence: Associations with STEM career choice

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ABSTRACT

The purpose of this study was to determine if there were distinct developmental trajectories of math anxiety during adolescence and if these trajectories predicted later STEM career choice. The study also evaluated whether the trajectories varied in relation to gender and race/ethnicity. Data were drawn from Longitudinal Study of American Youth-younger cohort that consisted of 3116 nationally representative sample of 7th grade students (48% Female, 70% European American) that were followed for 7 years. The results revealed four heterogeneous math anxiety trajectory groups: *consistently low (34.68%), decreasing (23.72%), increasing (21.90%), and consistently high (20.12%)*. Trajectories varied with regard to race/ethnicity but not gender. Membership in *consistently low* or *decreasing* trajectory predicted later STEM career choice. The findings suggest that preventive interventions may benefit from targeting math anxiety during adolescence.

Math anxiety is defined 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" (Richardson & Suinn, 1972, p. 551). Math anxiety is one of the most prevalent types of academic anxieties in school (see Cassady, 2010). For instance, the 2012 Program for International Student Assessment report (Organization for Economic Co-operation and Development [OECD], 2015) indicated that on average about 30% of 15-year students across 65 nations experience high levels of math anxiety. Math anxiety is negatively associated with math performance (e.g., Ashcraft & Moore, 2009; Hembree, 1990; Lee, 2009; Ma, 1999). In addition to its negative cognitive consequences, math anxiety can lead to avoidance of math and related tasks (Ashcraft, Krause, & Hopko, 2007). Indeed, evidence shows that math anxiety is positively associated with avoidance of math courses thereby influencing individuals' career pursuit (Hembree, 1990). These patterns are acutely troubling given the potential of math anxiety to deplete the Science, Technology, Engineering and Mathematics (STEM) pipeline in the U.S. and elsewhere (Beilock & Maloney, 2015; Foley et al., 2017). Despite the prevalence and its debilitating effects on math performance and its potential negative impact on a nation's resource base in STEM, we know little about the development of math anxiety during adolescence— a developmental period during which a more realistic occupational identity emerges (Porfeli & Lee, 2012). Moreover, we know little about how the development of math anxiety relates to core demographic variables such as gender and race/ethnicity— variables that play a key role in math participation (Catsambis, 1994). More importantly, little is known about how math anxiety during adolescence is associated with later adult outcomes such as STEM career choice. A better understanding of the development of math anxiety during adolescence is essential in providing targets for prevention intervention to alleviate math anxiety and enhance youth's interest in STEM— an ongoing national effort (Morrell & Parker, 2015).

This study attempted to address the aforementioned gaps in the literature. To this end, the study had three objectives. The first

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objective was to investigate the developmental trajectories of math anxiety in a large sample of adolescents from 7th to 12th grade using a person-centered approach (Laursen & Hoff, 2006) based on socio-cognitive models of math anxiety (e.g., Ashcraft et al., 2007; Beilock, Schaeffer, & Rozek, 2017). These models hold that math anxiety emerges as a result of complex person-by-situation transaction. Thus, the models stress the importance of both personal (e.g., low self-confidence) and environmental (e.g., negative math classroom climate) factors in the development and maintenance of math anxiety (Ashcraft et al., 2007; Beilock et al., 2017; Newstead, 1998). Given the diversity of individual characteristics and the dynamic nature of social and learning environments students encounter in school, there might exist diverse developmental trajectories of math anxiety (Ashcraft et al., 2007).

Although there is an extensive body of literature on the nature and cognitive consequences of math anxiety (for reviews see Ashcraft & Moore, 2009; Dowker, Sarkar, & Looi, 2016; Suárez-Pellicioni, Núñez-Peña, & Colomé, 2016), we know little about the developmental changes in math anxiety. Indeed, there is a widespread claim that math anxiety increases overtime (see Dowker et al., 2016). Nevertheless, to date, to the best of the researcher's knowledge, only three longitudinal studies have examined changes in math anxiety. In the first study, Wigfield and Eccles (1989) investigated changes in math anxiety over two years in a sample of early adolescents transitioning to junior high school. In this study, the authors found a decrease in math anxiety from grade 6 (elementary school) to grade 7 (junior high school). In the second study, Ahmed, van der Werf, Minnaert and Kuyper (2013) investigated the changes in math anxiety at three measurement occasions over a year among a sample grade 7 students. The authors found that math anxiety was fairly stable over time. In the third study, Madjar, Zalsman, Weizman, Lev-Ran and Shoval (2016) examined changes in math anxiety from beginning of sixth grade to the end of seventh grade, with two measurement occasions in between, and found no change in math anxiety overtime. Such inconsistencies in the previous research along with the often used group-based approach to identify distinct groups of math anxious individuals as low, medium and high based on arbitrary cut of scores on math anxiety measures (Ashcraft & Moore, 2009) suggest that there may be clusters of individuals following distinct developmental trajectories.

To more fully understand diverse developmental trajectories of math anxiety, it is imperative to examine group differences in the trajectories. Thus, the second objective of this study was to examine whether and how two core demographic variables: gender and race/ethnicity are associated with trajectories of math anxiety. The extant literature suggests that students' levels of math anxiety may vary across gender and racial/ethnic groups. An extensive body of literature indicates that females experience higher levels of math anxiety than males (see Dowker et al., 2016; Else-Quest, Hyde, & Linn, 2010; Hembree, 1990). For instance, in their meta-analysis of gender differences in math achievement and math attitude, Else-Quest et al. (2010) found that despite very small gender differences in mathematics performance, girls reported significantly higher math anxiety than boys. Evidence regarding racial/ethnic differences in math anxiety, albeit limited, shows interesting diversity. For instance, Hembree (1990) meta-analysis found that whereas Hispanics reported higher levels of math anxiety than Whites, there were no significant differences between Blacks and Whites. In a recent study that utilized a nationally representative sample of adolescents, Hispanics reported higher levels of math anxiety than their White counterparts but Blacks did not differ from Whites (Cheema & Sheridan, 2015). Despite such group variations in levels of math anxiety, no study has examined whether gender and race/ethnicity are associated with adolescents having distinct developmental trajectories. Thus, the current study investigated whether and how math anxiety trajectories varied in relation to gender and race/ethnicity. To avoid possible confounding effect of socioeconomic status (SES), the current study controlled for parental education—a stable indicator of SES (Sirin, 2005). Understanding how the development of math anxiety varies as a function of sociodemographic characteristics is essential for advances in math anxiety etiology and prevention.

The third objective of this study was to assess the extent to which trajectories of math anxiety during adolescence are associated with later STEM career choice. Theoretically, math anxiety is posited to lead to avoidance of math and related courses and careers (Ashcraft, 2002; Ashcraft et al., 2007). Although a considerable amount of literature has been published on math anxiety and its relationship with math performance, only limited numbers of studies have examined the relations between math anxiety and behavioral intentions such as intent to take more math courses. Hembree (1990) meta-analysis of a handful of studies showed that math anxiety is negatively associated with intent to take more math courses in high school and beyond. Based on such studies, scholars claim that math anxiety steers individuals away from STEM careers (Ashcraft, 2002; Beilock & Maloney, 2015). Yet, to the best of the researcher's knowledge no longitudinal study to date has examined the relationship between math anxiety and STEM career attainment. Whereas previous studies have certainly added to our knowledge of the negative impact of math anxiety on intentions to take more or advanced math courses, we know little about whether a high and stable math anxiety during adolescence is associated with lesser likelihood of choosing STEM careers during adulthood. The current study attempted to fill this gap by examining the associations between math anxiety trajectory membership and STEM career choice. Because evidence shows that parents with STEM occupations influence their children's college major choice in STEM (Moakler & Kim, 2014), parental STEM occupation was taken into account when predicting STEM career choice by math anxiety trajectories.

1. The present study

The objectives of this study were:1) to identify groups of individuals who follow distinct development trajectories of math anxiety, 2) to examine if gender and race/ethnicity differentiate math anxiety trajectory groups and 3) to examine the relationship between membership in math anxiety trajectory groups and STEM career choice. With regard to the first objective, because no previous study has examined math anxiety trajectory clusters, no specific hypothesis was formulated regarding the specific number of expected trajectory groups. Nevertheless, based on previous cross-sectional (see Dowker et al., 2016; Hembree, 1990) and longitudinal (Ahmed, van der Werf, Kuyper, & Minnaert, 2013; Madjar, Zalsman, Weizman, Lev-Ran, & Shoval, 2016; Wigfield & Eccles, 1989) studies as well as existing empirical approaches to the study and classification of math anxiety (Ashcraft & Moore, 2009; Ashcraft et al., 2007), four trajectories were expected: decreasing, increasing, low and high trajectories. Concerning the second objective,