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Relationships of mathematics performance, control and value beliefs with cognitive and affective math anxiety

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ABSTRACT

The study examines whether mathematics performance, control beliefs (self-concept in mathematics), and value beliefs (regarding domain interest and achievement outcome) differentially relate to cognitive math anxiety (worry about failure) and affective math anxiety (nervousness) and, thus, support the differentiation between these two math anxiety components. A sample of 368 fourth grade students reported cognitive and affective math anxiety and self-perceived beliefs, and completed a mathematics test. Confirmatory factor analyses supported the differentiation between cognitive and affective math anxiety. Multivariate regression analyses on the cross-sectional data revealed that mathematics performance was differentially stronger negatively related to cognitive math anxiety than to affective math anxiety, whereas control beliefs related stronger negatively to affective as compared to cognitive math anxiety. Therefore, longitudinal studies should investigate whether these differential relation patterns also manifest in the long term and occur reciprocally, which may indicate differential developmental mechanisms and effects of cognitive and affective math anxiety.

1. Introduction

Becoming proficient in mathematics is fundamental for economic and social participation because many professions and situations in everyday life demand the application of math operations (Patton & Cronin, 1997). Like all other school-related performances, achievement in mathematics is associated with cognitive (e.g., working memory; Ashcraft & Kirk, 2001), motivational (e.g., mathematics self-concept and domain interest; Ahmed, Minnaert, Kuyper, & van der Werf, 2012), and affective characteristics of the learner (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011). Affective characteristics include achievement emotions, which are directly linked to ongoing achievement activities (e.g., enjoyment when dealing with mathematics tasks in class) or to outcomes of these activities (e.g., anxiety of failure).

Math anxiety is one of the most studied outcome emotions in mathematics that has received considerable attention in educational and psychological research because of its assumed negative associations with cognitive and motivational variables (e.g., mathematical achievement, self-perceived competences, and values; Ashcraft, 2002; Frenzel, Pekrun, & Goetz, 2007; Hembree, 1990; Ma, 1999; Schwarzer, Seipp, & Schwarzer, 1989; Suárez-Pellicioni, Núñez-Peña, & Colomé, 2015; Wigfield & Meece, 1988). Math anxiety can be defined as the feeling of tension, apprehension, or fear in the processing of mathematical problems in daily life and in school settings (Ashcraft, 2002). Long term studies suggest that math anxious individuals exhibit negative attitudes toward activities involving mathematical problems (Ahmed et al., 2012; Hembree, 1990; Ho et al., 2000; Kyttälä & Björn, 2010; Ma, 1999; Schwarzer et al., 1989). Accordingly, they tend to avoid mathematics oriented situations altogether (Hembree, 1990; Maloney & Beilock, 2012) and take, for example, courses in school or choose college majors that are less related to mathematics, which may in turn limit their career choice options (Scarpello, 2005).

Although math anxiety has overlaps with general test anxiety, both constructs can be differentiated from each other (Hembree, 1990; Hunsley, 1987). As shown for general test anxiety (Hembree, 1988; Liebert & Morris, 1967; Schwarzer et al., 1989), math anxiety is assumed to be a multidimensional construct, including two psychological dimensions: *emotionality* represents the affective component and includes feelings of nervousness, tension, and unpleasant physiological reactions. Conscious *worry* or concern is the cognitive component and involves self-deprecatory thoughts about one's performance, negative expectations, and preoccupation with anxiety-causing situations (Wigfield & Meece, 1988). Research on general test anxiety indicates a strong association between the affective (emotionality) and the cognitive (worry) component ($0.67 \leq r \leq 0.78$, $p < 0.01$, cf. Hembree, 1990), whereas there are only a few studies on math anxiety examining this

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relationship. In contrast to general test anxiety research, low to moderate correlations between cognitive and affective math anxiety ($0.25 \leq r \leq 0.38$) were found (Ho et al., 2000; Kazelskis, 1998; Wigfield & Meece, 1988), thus, providing evidence to differentiate between the two components.

Although there is a vast body of research on the developmental mechanism and the effects of math anxiety, most studies do not differentiate between the affective and the cognitive component but report an overall (sum or mean) score (Ashcraft & Kirk, 2001; Baloğlu & Koçak, 2006; Frenzel et al., 2007; Radišić, Videnović, & Baucal, 2015; Ramirez, Gunderson, Levine, & Beilock, 2013; Suárez-Pellicioni et al., 2015; Suinn, 1972; Vukovic, Kieffer, Bailey, & Harari, 2013). Given the moderate correlations and the low proportion of common variance between these two dimensions (Wigfield & Meece, 1988), it is yet unclear whether variables that have been discussed as critical antecedents and consequences (e.g., control and value beliefs, mathematics performance; Pekrun, 2006) are differentially associated with affective and cognitive math anxiety.

Building on the control-value theory of achievement emotions (Pekrun, 2006), which served as the theoretical framework in the present study, we aimed to explore whether mathematics performance and control and value beliefs differentially relate to math anxiety components and thus support their differentiation. The results of this cross-sectional study may provide first indications whether further longitudinal research on differential developmental mechanisms and effects of cognitive and affective math anxiety is needed.

1.1. Control-value theory of achievement emotions

In the last few years, appraisal theories have been proven useful to describe the origins of human emotions with several attributional antecedents (e.g., controllability, situational and motivational state, and valence; Pekrun, 2006; Roseman, Antoniou, & Jose, 1996; Weiner, 1985). The control-value theory of achievement emotions (Pekrun, 2006) integrates core principles from appraisal theories (Weiner, 1985) and considers control and value appraisals as the most critical antecedents of students' emotional experiences. According to this theory, control-related appraisals include self-perceived competence, outcome expectancies, and causal attributions. Value-related appraisals involve the value of an activity in a specific domain (*domain value*), that is, individuals may enjoy mathematics because they appreciate the activity of dealing with mathematical problems and learning new mathematical procedures. Value-related appraisals may also refer to the importance of an achievement outcome (*achievement value*), for example, achieving a good grade in order to meet the expectations of significant others such as parents and teachers (cf. Frenzel et al., 2007). Furthermore, valuing an activity or outcome for its own sake refers to the intrinsic value, whereas valuing an activity or outcome because of its usefulness for achieving a specific goal refers to the extrinsic value.

Habitual control beliefs (e.g., self-concept of ability) and value beliefs, (e.g., domain interest and achievement value) are assumed to develop through repeated experiences within different settings (e.g., success or failure in a mathematics test) and to evoke appraisals in specific situations. The result of control and value beliefs is thought to elicit positive or negative emotions related to learning activities (e.g., enjoyment) and to learning outcomes (e.g., pride, anxiety). For example, the theory proposes that enjoyment results from high control beliefs along with high domain values, whereas pride is expected from a combination of high control beliefs and high achievement values. By contrast, low control beliefs along with high achievement values and low domain values should evoke anxiety (Pekrun, 2006). Previous research clearly indicates specific patterns for several emotions that are stable across different domains, cultures, and gender (Frenzel et al., 2007; Goetz, Frenzel, Lüdtke, & Hall, 2010; Lichtenfeld, Pekrun, Stupnisky, Reiss, & Murayama, 2012).

Furthermore, positive emotions (e.g., enjoyment, pride) are assumed to facilitate the use of flexible learning and self-regulation strategies and to foster intrinsic and extrinsic motivation (Pekrun, 2006). Negative emotions, such as anxiety, may however have different effects on students' learning. Although they could promote extrinsic motivation to avoid failure (cf. Ho et al., 2000), it is likely that the negative effects on academic performance outweigh the advantageous consequences. For example, anxiety was shown to impede intrinsic motivation and to foster the use of less flexible learning strategies, such as rehearsal (Pekrun, 2006; Ramirez, Chang, Maloney, Levine, & Beilock, 2016).

The control-value theory further assumes reciprocal relationships between emotions and their antecedents, including mathematics performance and control and value beliefs (Pekrun, 2006). By implication, control and value beliefs are thought to mediate the effect of learning experiences (e.g., grades or performances) on emotions and vice versa. In the next two sections, we summarize empirical findings on math anxiety and its relations with mathematics performance and control and value beliefs, which provide evidence for the core assumptions of the control-value theory.

1.2. The relationship between mathematics performance and math anxiety

Previous research repeatedly found moderately negative associations between math anxiety and mathematical problem solving and achievement ($-0.27 \leq r \leq -0.34$, $p < 0.05$; cf. Hembree, 1990; Ma, 1999) across different age groups (Ashcraft, 2002; Ashcraft & Moore, 2009; Hembree, 1990; Ma, 1999; Ma & Xu, 2004; Vukovic et al., 2013). According to the control-value theory, high math anxiety is assumed to be the cause (interference model) as well as the effect (deficits model) of low mathematics performance (Hembree, 1990; Ma & Xu, 2004). For example, the study by Kyttälä and Björn (2010) supports the deficits model. The authors applied path analyses and showed that mathematics performance of Finnish students in 8th grade predicted affective math anxiety in 9th grade indirectly through self-efficacy in mathematics. However, math anxiety did not predict mathematics performance at the end of ninth grade over and above prior performance. Similarly, Ma and Xu (2004) investigated the causal ordering between affective math anxiety and mathematics performance in students between 7th and 12th grades. Low achievement in mathematics consistently predicted higher levels of affective math anxiety (deficits model) but not vice versa. By contrast, Vukovic et al. (2013) found evidence for the interference model. Specifically, the authors showed that higher levels of math anxiety (including cognitive and affective components) of second grade children predicted lower calculation skills and reduced performance in mathematical applications (word problems, algebra, and probability) in third grade when controlling for early numeracy skills.

According to the interference model, worrisome thoughts are assumed to exert the negative effect on performance by co-opting the limited resources of the working memory system, presumably in the central executive (Baddeley, 2001), which are otherwise used for task processing (Ashcraft & Kirk, 2001; Derakshan & Eysenck, 2009). By implication, the cognitive (worry) component of anxiety should be stronger related to performance than the affective (emotionality) component. For general test anxiety, Hembree (1988) and Schwarzer et al. (1989) provided evidence for this assumption in two meta-analyses, indicating that the cognitive component was stronger negatively ($-0.31 \leq r \leq -0.25$, $p < 0.05$) associated with test performance than was the affective component of test anxiety ($-0.19 \leq r \leq -0.15$, $p < 0.05$). By contrast, the few studies on math anxiety that investigated these relationships point into a different direction. Specifically, Wigfield and Meece (1988) showed in a study with 6th through 12th grade students that affective math anxiety correlated negatively with students' mathematics performance, whereas the cognitive scale was not at all related to mathematics performance. Similarly, Ho et al.