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Development of sex differences in math achievement, self-concept, and interest from grade 5 to 7☆

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ABSTRACT

Sex differences in mathematics achievement have been a controversial topic in educational psychology for a long time. This study sheds light on the developmental aspects of sex differences in math achievement and domain-specific motivational variables such as self-concept and interest. Using a *Reciprocal Effects Model* (REM), we analyzed 2,342 German fifth to seventh grade students who participated in a large-scale longitudinal study. Math self-concept was validated as a consistent predictor of subsequent achievement and interest for both sexes, supporting the *self-enhancement* part of the REM using test-scores and teacher-assigned grades. However, math achievement affects subsequent self-concept inconsistently (i.e., the *skill development* part). Although the bivariate relationships between the constructs were homogeneous across sex and over time, there were large sex differences in the motivational constructs, but not in the achievement measure regardless of achievement measures. The present findings underline the importance of considering both the mean and the covariance structure when describing sex differences in academic achievement. In addition, they also stress the impact of motivational constructs on educational achievement, which also have implications for sex-specific intervention programs in general.

1. Introduction

Sex differences in students' academic achievement have been a controversial topic among psychologists and educators for several decades (Halpern et al., 2007; Hyde, 2005). The study of sex differences in cognitive abilities has been seen as "a sociopolitical minefield, with serious implication for a wide range of public policies (e.g., affirmative action, compensatory education, pay equity)" (Halpern & LaMay, 2000, p. 230). Although the sex ratio among freshmen in Western universities is at least equal, women are often underrepresented in STEM study programs (science, technology, engineering, and mathematics) - in particular engineering, physical science, and computational science (Hyde, 2014). Small sex differences in math achievement in favor of boys have frequently been reported in secondary education (Brunner et al., 2013), but they are not the major factor explaining differences in the enrollment for STEM subjects. In this context, researchers have emphasized the importance of sex-related differences in motivational constructs such as domain-specific self-concept and interest in course selection and educational choices (e.g., Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005). Given that STEM subjects have been recognized as a critical filter to a higher salary and esteemed jobs, sex differences in STEM abilities or motivation at any age or educational level are of particular interest. Moreover, to tap the large talent pool of female students and to increase equity between sexes regarding participation in STEM studies, it is important to understand more thoroughly the developmental interplay between educational achievement and motivational constructs across sex groups.

In the literature on the interplay of academic achievement and motivational constructs such as domain-specific self-concept and interest, there are three competing perspectives: The *skill development*

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theory (i.e., academic achievement as a major determinant of academic self-concept), the *self-enhancement theory* (i.e., self-concept as a primary determinant of academic achievement, Calsyn & Kenny, 1977), and the notion of *reciprocal relations* between academic achievement and self-concept which are mutually reinforcing (e.g., Marsh, 1990). The long-standing debate between proponents of skill development vs. self-enhancement has only superficially been settled with the introduction of the reciprocal effects model (Marsh & Craven, 2006) because the answer to the imminent and prevailing question which path is more prevalent is still pending. Consequently, reconsidering the prospect of causal order between math achievement and self-concept/interest has intriguing theoretical and practical implications.

The contribution of the present study is, therefore, threefold: First, we investigated the interplay between math achievement and self-concept and interest, respectively. That is, we study whether academic self-concept and interest have substantial effects on subsequent academic achievement (self-enhancement) or math achievement on the motivational constructs (skill-development). Second, sex-related comparisons in the REM context are only valid if the used measures are invariant over time and across sex groups (Cheung & Rensvold, 2002; Little, Preacher, Selig, & Card, 2007). In this regard, our study also likes to draw attention to the psychometric properties of the measure and an appropriate way of modeling longitudinal data. Third, we added to previous findings by studying the relations among math achievement (i.e., test-scores and grades) and motivational constructs (i.e., self-concept and interest) in a large sample of German secondary school students. In this respect, one aim of the present study is to provide further evidence for the reported literature findings, since "replication evidence is the gold standard by which scientific claims are evaluated" (p. 410, Bonett, 2012). In contrast, unfortunately, only a small number of the publications in psychology are replications (see also Makel, Plucker, & Hegarty, 2012).

1.1. Reciprocal relations between math achievement and self-concept

Math is a core subject in every school program, and success in math is strongly associated with math self-concept, which is defined as the subjective feeling and belief in one's competence in math (Marsh, 1989). In the debate on the causal order of motivational and cognitive constructs, two opposing perspectives were irreconcilable for a long time (Calsyn & Kenny, 1977). On the one hand, the *self-enhancement hypothesis* postulates that self-concept positively affects subsequent achievement via educational decisions, higher motivation, effort, and investment (Marsh & Yeung, 1997). According to this perspective, encouraging academic self-concept should stimulate students' achievement. On the other hand, the *skill-development hypothesis* postulates that achievement positively affects the academic self-concept, which is explained by the fact that students' evaluate their competence (i.e., self-concept) by comparing their performance/grades to others (i.e., social comparison, Möller & Pohlmann, 2010). If a student gets good grades and excels, he or she develops a positive self-concept, whereas students with low achievement develop a low academic self-concept. A contemporary perspective on this motivation-achievement debate is the *Reciprocal Effects Model* (REM), which integrates both ideas by assuming a mutually dependent positive relationship between academic self-concept and achievement over time (Marsh & Craven, 2006; Marsh, 1990). Differently worded, students who are competent in math develop a positive self-concept, and this self-concept, in turn, promotes students' academic performance.

A meta-analysis summarizing the empirical evidence of the *self-enhancement* hypothesis showed a weak to moderate positive relation from academic self-concept to later achievement within a given domain (Valentine, Dubois, & Cooper, 2004; see also Huang, 2011). Similarly, a meta-analysis of the *skill development* model revealed a strong positive path from academic achievement to self-concept (Möller, Pohlmann, Köller, & Marsh, 2009). Moreover, several longitudinal comparable *reciprocal relations* have been found between math achievement and self-concept (Möller, Retelsdorf, Köller, & Marsh, 2011; Pinxten, Marsh, De Fraine, Van Den Noortgate, & Van Damme, 2014). Nonetheless, findings of the causal relationship between academic self-concept and achievement are inconsistent (Marsh & Martin, 2011) and may be moderated by the school subject and the time point in the course of education. For example, Chen, Yeh, Hwang, and Lin (2013) found reciprocal effects for Taiwanese high-school students in math, but for the language domain, only the skill development part was supported. Moreover, the skill development model only holds for younger children, whereas the self-enhancement effects were present only for older students, revealing a developmental change in the reciprocal effects (Chen et al., 2013; Fraine, Damme, & Onghena, 2007). However, findings of other studies showed that the effect of academic self-concept on achievement was unrelated to age and the school type (Guay, Marsh, & Boivin, 2003; Valentine & DuBois, 2005). Thus, currently, there is insufficient evidence to conclude that the REM varies with age (Marsh, Byrne, & Yeung, 1999; Valentine & DuBois, 2005).

Other explanations for these diverging results might be: (a) different operationalization of math achievement (grades vs. test-scores), (b) the breadth of the definition of math self-concept, for example, math enjoyment and competence beliefs (Else-Quest, Hyde, & Linn, 2010; Pinxten et al., 2014), as well as math confidence (Else-Quest et al., 2010; Ganley & Lubienski, 2016) as part of self-concept, (c) different methodological approaches, that is linear regression with manifest indicators vs. latent variable modeling (Marsh et al., 2005; von Maurice, Dörfler, & Artelt, 2014), (d) the average ability level of the sample (e.g., academic track only, see also Marsh et al., 2017), and (e) design of the study, that is, cross sectional vs. longitudinal (Else-Quest et al., 2010; Marsh et al., 2005). In the present study, we investigated the causal relationship of math self-concept and achievement across sex groups with standardized achievement test-score and teacher-assigned grade at a latent level using longitudinal data in a heterogeneous sample of secondary school students.

1.2. Reciprocal relations between math achievement and interest

There are various conceptualizations of interest (Hidi & Renninger, 2006). In line with the person-object concept of Krapp (2002), we define interest as a characteristic of a relation between a student and a domain. For example, students with high interest are characterized by a consistently high cognitive commitment and emotional involvement in math. In this sense, interest is a) considered domain-specific, b) comprised of a cognitive and an affective component, c) built and nourished over the school career, and d) relatively stable over a variety of situations and over time (Jansen, Lüdtke, & Schroeders, 2016; Krapp, 2002; Marsh et al., 2005). The development of math interest and achievement is intertwined. Math interest is at the central of self-determined activities and likely to be reciprocally related with achievement (Garon-Carrier et al., 2016; Marsh et al., 2005; Ryan & Deci, 2000). That is, students interested in math will be more persistent and keen in pursuing math-related activities and, thus, more likely achieve higher grades/test-scores. Likewise, better grades in math should encourage and motivate students (Ryan & Deci, 2000).

The current literature on REM, including interest as a motivational construct, is scarce and often yields contradictory results: Some researchers (e.g., Liu, 2009; Pinxten et al., 2014; Yoon, Eccles & Wigfield, 1996) found a positive mutual relation between math interest and achievement, while others found a significant skill development effect, but no self-enhancement effect (Ganley & Lubienski, 2016). In contrast, Marsh et al. (2005) reported little or no effect of academic achievement on interest, but a significant positive self-enhancement effect. Whereas, Köller, Baumert, and Schnabel (2001) argued that early math interest might yield an indirect effect on course selection, which in turn affects math achievement. This notion is also in line with research emphasizing the importance of interest for course enrollment (in comparison to prior