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Direct and indirect effects of self-concept of ability on math skills

Dan Cai[a,*], Jaana Viljaranta[b], George K. Georgiou[c]

[a] Department of Psychology, Shanghai Normal University, Shanghai, China
[b] School of Educational Sciences and Psychology, University of Eastern Finland, Finland
[c] Department of Educational Psychology, University of Alberta, Edmonton, Canada

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ABSTRACT

The purpose of this study was to examine the direct and indirect effects of self-concept of ability on two math skills (calculation fluency and problem solving) in three grade levels (2, 4, and 7) in China. Two hundred forty-one children (80 Grade 2, 76 Grade 4, and 85 Grade 7) from Shanghai (China) were assessed on calculation fluency and problem solving. They also responded to a questionnaire measuring their math self-concept and interest. Teachers rated the children's task-focused behavior. The results of path analysis showed that self-concept of ability had a direct effect on calculation fluency in Grade 7 and on problem solving in Grades 4 and 7. The results of multiple mediation analyses further showed that part of self-concept of ability's effects on problem solving in Grades 4 and 7 were mediated by task-focused behavior. Taken together, our findings suggest that, even in the context of Chinese culture, self-concept of ability is important for math skills, particularly when predicting problem solving.

1. Introduction

According to one of the most popular theories of motivation, the expectancy-value theory of achievement motivation (see Eccles, 2005; Eccles et al., 1983; Meece, Wigfield, & Eccles, 1990; Wigfield & Eccles, 2000, 2002), students who have a positive self-concept of their ability and who are interested in specific academic subjects or tasks (e.g., math, reading) are more focused and adaptively engaged in those tasks, which subsequently leads to better academic performance. Several studies have provided evidence in support of this theoretical account (e.g., Ecalle, Magnan, & Gibert, 2006; Gottfried, 1990; see also Valentine, DuBois, & Cooper, 2004, for a review). In addition, according to the expectancy-value theory of achievement motivation, students' self-concept of ability influences their subjective task values; a notion that has also received empirical support (e.g., Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005; Viljaranta, Tolvanen, Aunola, & Nurmi, 2014). Students who hold a positive self-concept in a specific subject are more likely to be interested in that subject, which, then, provides a basis for adaptive, focused behavior in achievement-related situations.

Despite the popularity of the expectancy-value theory of achievement motivation, previous studies examining the relationship between the components of this theoretical model and mathematics ability have several limitations: First, even though the theory involves different aspects of motivation (i.e., self-concept of ability, interest, and task-focused behavior) that may contribute to mathematics ability, most previous studies have focused on only one or two aspects of this model at a time (e.g., Georgiou, Manolitsis, Nurmi, & Parrila, 2010; Guo, Marsh, Parker, Morin, & Yeung, 2015; Jõgi & Kikas, 2016; Pajares & Miller, 1994; Seegers & Boekaerts, 1993) and none has examined if interest and task-focused behavior mediate the relationship between self-concept of ability and mathematics performance. Second, most previous studies on the expectancy-value theory of achievement motivation have been conducted in North America or in Europe (e.g., Hirvonen, Tolvanen, Aunola, & Nurmi, 2012; Köller, Baumert, & Schnabel, 2001; Marsh et al., 2005) and we do not know if the same relations hold in other cultures (e.g., East Asian). Because of the widely held belief among Chinese families that a child achieves for his/her family (e.g., Qu, Pomerantz, & Deng, 2016), Chinese children are expected to invest effort in all subject areas. This implies that the effect of some motivational aspects (e.g., self-concept of ability) on mathematics ability in the Chinese culture may not be significant. Finally, previous studies have examined the effects of self-concept of ability on either a math composite score (derived from combining scores in calculations and problem solving) or on math grades in school and we do not know if the effects of self-concept of ability vary as a function of the type of mathematics outcome. It is possible that the reported correlations with these outcome measures misrepresent the true relationship between self-concept of ability and different types of math skills. For example, because calculation fluency requires fact retrieval from long-term

* Correspondence author at: Department of Psychology, Shanghai Normal University, No. 100, Guilin Road, Shanghai 200234, China.
E-mail address: caidan@shnu.edu.cn (D. Cai).

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memory and is heavily practiced by Chinese children from the age of 4 or 5, it should not elicit any effects from self-concept. On the other hand, problem solving is one of the most important tasks through which children can learn to select and apply appropriate strategies for solving real-world problems. It involves multiple domains (i.e., reading and mathematics) and is considered a form of higher cognitive processing skill that requires coordination of multiple cognitive systems (e.g., Andersson, 2007; Swanson, 2006; Wang, Fuchs, & Fuchs, 2016) and persistence before a solution is reached (e.g., Aunola, Nurmi, Lerkkanen, & Rasku-Puttonen, 2003; Metsäpelto, Pakarinen, Kiuru, Poikkeus, Lerkkanen, et al., 2015). Given that children who believe on their abilities invest more effort in reaching a solution, problem solving should elicit strong effects from self-concept of ability. Thus, the purpose of this study was to test the direct and mediated (through interest and task-focused behavior) effects of self-concept of ability on two math skills (calculation fluency and problem solving) in three different grades (2, 4, and 7) in China.

1.1. The role of non-cognitive variables in mathematics

To date, the majority of studies examining the predictors of mathematics performance has focused on cognitive skills such as general intelligence (e.g., Passolunghi, Mammarella, & Altoè, 2008), working memory (e.g., Swanson & Kim, 2007), executive functioning (e.g., Cragg & Gilmore, 2014), approximate number system (e.g., Passolunghi, Cargnelutti, & Pastore, 2014), counting (e.g., Koponen et al., 2016), and number sense (e.g., Jordan, Glutting, & Ramineni, 2010). Despite the success of this line of research in explaining a sizeable amount of variance in mathematics (50–60%), a significant amount of variance still remains unexplained.

As a result, several researchers turned their interest to non-cognitive factors such as quality of instruction (e.g., Charalambous, 2015; Charalambous & Kyriakides, 2017), home literacy environment (e.g., Deng, Silinskas, Wei, & Georgiou, 2015; Manolitsis, Georgiou, & Tziraki, 2013; Niklas & Schneider, 2013) and motivation (e.g., Chiu & Xihua, 2008; Steinmayr & Spinath, 2009; Suárez-Álvarez, Fernández-Alonso, & Muñiz, 2014; Viljaranta, Lerkkanen, Poikkeus, Aunola, & Nurmi, 2009) that may also contribute to mathematics performance. In this study, we sought to better understand the contribution of a motivational concept, namely of self-concept of ability. The term self-concept of ability refers to students' beliefs regarding their competence in upcoming tasks or in the task at hand, and in Eccles' theory these beliefs have been conceptualized as ability beliefs and success expectancies. Even though expectancies and ability beliefs are theoretically distinct concepts, empirically they have been found to be inseparable (Eccles et al., 1983; Wigfield & Eccles, 2000), and in the literature, the term 'self-concept of ability' has often been used to refer to both of these self-evaluative judgements (e.g., Aunola, Leskinen, Onatsu-Arvilommi, & Nurmi, 2002; Nurmi & Aunola, 2005; Pesu, Viljaranta, & Aunola, 2016). In the present study, this term is used to refer to children's judgements about their ability in the area of math.

1.1.1. The role of self-concept of ability in mathematics performance

To date, several studies have shown that children's self-concept of ability is a significant correlate of mathematics performance: students' higher beliefs about their abilities are associated with higher mathematics performance (see Denissen, Zarrett, & Eccles, 2007; Marsh & Yeung, 1997; Pajares & Miller, 1994; Rao, Moely, & Sachs, 2000; see also Marsh & Craven, 2006; Valentine et al., 2004). Lee (2009), for example, reported an average correlation of 0.23 between self-concept of ability and mathematics performance among the 41 countries that participated in PISA 2003.[1] In turn, in their meta-analysis, Möller, Pohlmann, Köller, and Marsh (2009) found that the mean correlation between math self-concept and math achievement was 0.43. Studies by Eccles and colleagues (Eccles et al., 1983; see also Wigfield & Eccles, 2002) and Marsh and colleagues (e.g., Marsh et al., 2005; Marsh & Yeung, 1997; see also Marsh & Craven, 2006) have also shown that, especially among adolescents, self-concept of ability is one of the strongest predictors of subsequent performance in mathematics, surviving the statistical control of even previous levels of mathematics performance.

1.1.2. The mediating role of interest and task-focused behavior

However, self-concept of ability may not only predict mathematics performance directly, but also indirectly through the effects of interest and task-focused behavior (Eccles, 2005; Eccles et al., 1983; Wigfield & Eccles, 2000). Interest (as the only dimension of task values that younger children are able to clearly distinguish; see Eccles, Wigfield, Harold, & Blumenfeld, 1993) is a domain-specific concept referring to liking an activity and the enjoyment one gets from engaging in an activity. In turn, task-focused behavior, defined as the level of engagement a person demonstrates when encountered with challenging tasks (Aunola, Leskinen, et al., 2002; Aunola, Nurmi, Niemi, Lerkkanen, & Rasku-Puttonen, 2002), encapsulates the ways in which individuals try to deal with challenging learning tasks. Therefore, it represents the behavioral side of motivation in Eccles et al.' (1983) model.

According to the expectancy-value theory of achievement motivation, higher self-concept of ability contributes to higher interest, which can lead to academic engagement, typically associated with positive affect and persistent engagement in related tasks (similar to the concept of task-focused behavior used in our study), which, in turn, can lead to learning gains and higher school grades. Unfortunately, the evidence in support of both predictions is only indirect. More specifically, studies have shown that positive self-concept leads to increased effort and task-focused behavior in subsequent learning situations (e.g., Aunola et al., 2003; Eccles et al., 1983), and that increased levels of effort and task-focused behavior predict mathematics performance (e.g., Aunola, Leskinen, et al., 2002; Aunola, Nurmi, et al., 2002; Hirvonen et al., 2012; Metsäpelto et al., 2015). Likewise, studies have shown that self-concept of ability predicts later interest (e.g., Marsh et al., 2005; Viljaranta et al., 2014) and that high interest predicts later achievement (e.g., Aunola, Leskinen, & Nurmi, 2006; Köller et al., 2001; Viljaranta et al., 2009). To our knowledge, no studies have examined the role of both interest and task-focused behavior as mediators of the relationship between self-concept of ability and mathematics performance.

2. The present study

The purpose of the present study was two-fold: (a) to examine if self-concept of ability has a significant effect on two math skills (calculation fluency and problem solving) in three grade levels (2, 4, and 7) in China, and (b) to examine whether interest and task-focused behavior mediate the effects of self-concept of ability on math skills. For that purpose, we developed and tested a model (see Fig. 1) that includes both direct and indirect effects from self-concept of ability to the two math skills.

We tested the following hypotheses:

1. Self-concept of ability will have a positive effect only when predicting problem solving.
2. Self-concept of ability will exert both direct and indirect (through interest and task-focused behavior) effects on problem solving.

As indicated earlier in this introduction, one of the important contributions of this study is that it examines the role of self-concept of ability in mathematics performance in an East Asian culture. Obviously, any theory (including the expectancy-value theory of achievement motivation) needs to be validated across different cultures. However,

[1] However, the correlation between self-concept and mathematics in Hong Kong and Macau (China) was 0.34 and 0.32, respectively.