pedocs
Open Access Erziehungswissenschaften

DIPF

Arens, A. Katrin; Marsh, Herbert W.; Craven, Rhonda G.; Yeung, Alexander Seeshing; Randhawa, Eva; Hasselhorn, Marcus

Math self-concept in preschool children. Structure, achievement relations, and generalizability across gender

formal und inhaltlich überarbeitete Version der Originalveröffentlichung in:
formally and content revised edition of the original source in:
Early childhood research quarterly (2016) 36, S. 391-403

Bitte verwenden Sie beim Zitieren folgende URN /
Please use the following URN for citation:
urn:nbn:de:0111-pedocs-193274 - *http://nbn-resolving.org/urn:nbn:de:0111-pedocs-193274*
DOI: 10.1016/j.ecresq.2015.12.024 - *http://dx.doi.org/10.1016/j.ecresq.2015.12.024*

Nutzungsbedingungen

Dieses Dokument steht unter folgender Creative Commons-Lizenz: http://creativecommons.org/licenses/by-nc-nd/4.0/deed.de - Sie dürfen das Werk bzw. den Inhalt unter folgenden Bedingungen vervielfältigen, verbreiten und öffentlich zugänglich machen: Sie müssen den Namen des Autors/Rechteinhabers in der von ihm festgelegten Weise nennen. Dieses Werk bzw. dieser Inhalt darf nicht für kommerzielle Zwecke verwendet werden und es darf nicht bearbeitet, abgewandelt oder in anderer Weise verändert werden.
Mit der Verwendung dieses Dokuments erkennen Sie die Nutzungsbedingungen an.

Terms of use

This document is published under following Creative Commons-License: http://creativecommons.org/licenses/by-nc-nd/4.0/deed.en - You may copy, distribute and transmit, adapt or exhibit the work in the public as long as you attribute the work in the manner specified by the author or licensor. You are not allowed to make commercial use of the work or its contents. You are not allowed to alter, transform, or change this work in any other way.

By using this particular document, you accept the above-stated conditions of use.

Kontakt / Contact:

peDOCS
DIPF | Leibniz-Institut für Bildungsforschung und Bildungsinformation
Informationszentrum (IZ) Bildung
E-Mail: pedocs@dipf.de
Internet: www.pedocs.de

Mitglied der Leibniz-Gemeinschaft

Math Self-concept in Preschool Children: Structure, Achievement Relations, and Generalizability across Gender

A. Katrin Arens (German Institute for International Educational Research)
Herbert W. Marsh (Australian Catholic University and Oxford University)
Rhonda G. Craven (Australian Catholic University)
Alexander Seeshing Yeung (Australian Catholic University)
Eva Randhawa (Educational University of Heidelberg, Germany)
Marcus Hasselhorn (German Institute for International Educational Research)

Author Note

This work was supported by a fellowship within the Postdoc-Program of the German Academic Exchange Service (DAAD). Data collection was carried out in the context of a large-scale longitudinal study in southern Germany (Project "Schulreifes Kind"). We thank the colleagues from Frankfurt (Jan-Henning Ehm, Hanna Wagner), Würzburg (Frank Niklas, Marie Pröscholt, Sandra Schmiedeler, Wolfgang Schneider, Robin Segerer) and Heidelberg (Isabell Keppler, Miriam Johnson, Hermann Schöler) who together with Marcus Hasselhorn and Eva Randhawa were responsible for realizing this large scale study. Correspondence regarding this investigation should be sent to A. Katrin Arens, German Institute for International Educational Research, Centre for Research on Education and Human Development and Centre for Research on Individual Development and Adaptive Education (IDeA), Schloßstr. 29, D-60486 Frankfurt am Main, Germany, Email: arens@dipf.de.

This is the prepublication version of the following manuscript:

Arens, A.K., Marsh, H.W., Craven, R.G., Yeung, A.S., Randhawa, E., & Hasselhorn, M. (2016). Math self-concept in preschool children: Structure, achievement relations, and generalizability across gender. *Early Childhood Research Quarterly, 36*, 391–403. http://doi.org/10.1016/j.ecresq.2015.12.024

This paper is not the copy of record and may not exactly replicate the authoritative document published in *Early Childhood Research Quarterly.*

Abstract

This three-wave, longitudinal study explored the math self-concept of German preschool children (*N* = 420) with respect to its differentiation into competence and affect components, cross-sectional and longitudinal relations to early math achievement, and invariance across gender. Findings demonstrated that preschool children's math self-concept can be separated into competence and affect components, with the competence component displaying higher relations to early math achievement than the affect component. The competence component but not the affect component was found to be related to prior math achievement, providing evidence of the skill-development model of self-concept–achievement relations in the preschool years. Boys and girls demonstrated similar self-concept–achievement relations and mean levels in the competence and affect components of math self-concept. Given so far little research on self-concept in preschool children, this study offers important insights and expands current knowledge.

Keywords: math self-concept; differentiation; preschool; achievement relations; gender differences

Math Self-concept in Preschool Children: Structure, Achievement Relations, and Generalizability across Gender

Students' academic self-concept can be generally defined as students' self-perceptions of competence in the academic domain (Shavelson, Hubner, & Stanton, 1976) and has been a widely examined and important construct in educational and developmental psychology. The importance of academic self-concept is due to its relations to a wide range of outcomes including achievement (Huang, 2011; Marsh & O'Mara, 2008; Valentine, DuBois, & Cooper, 2004), motivation (Nagengast et al., 2011; Wigfield & Eccles, 2000), effort (Trautwein, Lüdtke, Schnyder, & Niggli, 2006), and educational choices (Parker, Marsh, Ciarrochi, Marshall, & Abduljabbar, 2014). Besides investigating relations with outcome variables, researchers have invested considerable effort into studying the internal structure of academic self-concept and gender differences (Marsh & Craven, 2006; Marsh & O'Mara, 2008). Respective studies, however, predominantly focused on elementary and secondary school students, and less research has been conducted with children before the beginning of formal schooling (i.e., preschool or kindergarten children). Yet, due to cognitive limitations and differences in the learning environment, preschool children's academic self-concept might differ from that of school students. The present longitudinal study focuses on different research questions related to math self-concept in German preschool children. These questions address the possibility of further differentiating math self-concept into competence and affect components, its cross-sectional and longitudinal relations to early math skills, and the generalizability of findings across gender.

The Construct of Academic Self-concept

Twofold Multidimensional Structure

Academic self-concept was originally assumed to comprise math and verbal self-concepts as subcomponents (Shavelson et al., 1976). Math and verbal self-concepts have been found to be nearly uncorrelated leading to the accepted conceptualization of academic self-concept as a domain-specific construct with distinct math and verbal self-concepts (Marsh, 1990; Möller, Pohlmann, Köller, & Marsh, 2009). The domain specificity of academic self-concept is also incorporated in the Self-Description Questionnaires (SDQ), an extensively validated and widely used series of instruments to assess students' self-concept in different age groups (Byrne, 1996; Marsh, 2007). The SDQ instruments encompass separate math and verbal self-concept scales with items asking for students' self-perceptions of competence in the respective academic domains (i.e., math, verbal) as well as items addressing students' motivational and affective responses to these domains. The competence-related and affect-related items were originally combined to unified scales (Marsh, 2007). However, well-established theories on motivation in education differentiate between competence self-perceptions and affective-motivational constructs. For example, the expectancy-value model (Eccles & Wigfield, 1995; Nagengast et al., 2011; Wigfield & Eccles, 2000) conceptualizes the expectancy and value components as two separate, yet interacting constructs. Competence self-perceptions can be regarded as a subcomponent of the expectancy component while motivational and affective responses are conceptually similar to intrinsic value (liking, enjoyment, interest) as a subfacet of the value component. Hence, it might be reasonable to assume that competence-related and affect-related self-concept items form separate constructs. This assumption could be indeed supported in recent studies showing that math and verbal self-concepts can each be differentiated into a competence component depicting students' self-evaluation of competence and an affect component of students' motivational-affective reactions (Arens & Hasselhorn, 2015; Arens, Yeung, Craven, & Hasselhorn, 2011; Marsh, Craven & Debus, 1999; Marsh et al., 2013; Pinxten, Marsh, De Fraine, Van Den Noortgate, & Van Damme, 2014). This finding originates from confirmatory factor analyses (CFA) comparing a 1-factor model with a 2-factor model. The 1-factor model assumes a global factor for a domain-specific academic self-concept (e.g., math self-concept) which is defined by both competence and affect-related items. The 2-factor model states separate factors, one for the competence component and one for the affect component related to a domain-specific academic self-concept (e.g., math competence self-concept and math affect self-concept), each defined by only the competence-related or affect-related items.

Relations between Self-concept and Achievement

Research endeavors on academic self-concept trace back to the proposition that holding a high self-concept is an important outcome in its own right and yields positive impact on a wide range of desirable outcomes including academic achievement (Marsh, 2007; Marsh & O'Mara, 2008). Indeed, academic self-concept has been consistently found to be substantially related to academic achievement (Marsh & Craven, 2006). Self-concept–achievement relations follow a domain-specific pattern since the relation between math self-concept and math achievement is higher than the relation between math self-concept and verbal achievement – a finding that again demonstrates the domain specificity of academic self-concept (Marsh & Craven, 2006; Marsh & O'Mara, 2008).

The investigation of self-concept–achievement relations furthers substantiates the assumption of a distinction between competence and affect components within domain-specific academic self-concepts since both components share differential relations to outcome criteria. The competence component has been found to be more highly related to achievement (Arens et al., 2011; Marsh et al., 2013) whereas the affect component seems to be more highly associated with behavioral indicators including effort expenditure (Arens & Hasselhorn, 2015; Pinxten et al., 2014). Based on these findings, academic self-concept has been conceptualized as comprising a twofold differentiation: first, a differentiation into math and verbal domains (domain specificity), and second, a differentiation into competence and affect components (Arens et al., 2011).

Considering longitudinal relations between self-concept and achievement, originally, the skill-development model (achievement is assumed to impact upon self-concept) was contrasted with the self enhancement model (self-concept is supposed to be an antecedent of subsequent achievement; Caslyn & Kenny, 1977). Recent findings have suggested mutually reinforcing relations between self-concept and achievement and therefore argue in favor of the reciprocal effects model (REM; Marsh & Craven, 2006). The REM combines the assumptions of the skill-development and the self enhancement models as it proposes that self-concept is an outcome as well as an antecedent of achievement. The REM has been supported by a range of empirical studies (Huang, 2011; Marsh & Craven, 2006; Marsh & Martin, 2011) and has been found to be generalizable across different educational systems and cultures (Germany: Marsh & Köller, 2004; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005; Möller, Retelsdorf, Köller, & Marsh, 2011; Niepel, Brunner, & Preckel, 2014; Hong Kong: Marsh, Hau, & Kong, 2002; Taiwan: Chen,Yeh, Hwang, & Lin, 2013).

Gender Differences

Studies investigating gender differences in mean levels of academic self-concepts have generally found that such differences follow gender stereotypes. Hence, girls have been found to display higher mean levels of verbal self-concept whereas boys have been found to have higher mean levels of math self-concept (Fredricks & Eccles, 2002; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Marsh, 1989; Skaalvik & Skaalvik, 2004; Wilgenbusch & Merrell, 1999). Besides mean differences in academic self-concepts, other studies investigated whether boys and girls differ in the relations between academic self-concept and achievement. Stereotypic socialization processes including reinforcements, feedback, and expectations might lead boys to establish a stronger association between math achievement and math self-concept than girls (Marsh, 1993). However, existing studies have demonstrated gender-invariant instead of gender-stereotypic patterns of self-concept–achievement relations so that boys and girls demonstrated similar and not differential relations between math (verbal) self-concept and math (verbal) achievement (Helmke & van Aken, 1995; Marsh, Trautwein, et al., 2005; Marsh & Yeung, 1998; Valentine et al., 2004).

To sum up, considerable effort has been invested into research on the construct of academic self-concept including its structure, achievement relations, and gender differences. However, most of these studies have been conducted with elementary and secondary school students. Fewer studies have focused on the academic self-concept of young children who have not yet entered formal schooling and attend preschool.

Academic Self-Concept in Preschool Children

In the present study, we focus on German preschool children’s academic self-concept which might differ from that of school-age students for various reasons. Academic self-concept has been assumed to be influenced by experiences with and within the environment (Shavelson et al., 1976). In Germany, notable differences exist between the academic environment and learning experiences of preschool and school-age children. Children usually enter kindergarten at the age of three or four and stay there until entering the compulsory elementary school at about six years of age. In German kindergartens, no formal instruction is provided with respect to academic skills. Preschool children rather acquire and improve their skills by playful and informal interactions with peers, parents, and educators. Instruction and learning opportunities are adapted to an individual child’s learning preconditions and circumstances. Achievement feedback mainly aims to motivate a child for further learning and thus relies on intraindividual, temporal comparisons focusing on a child’s improvement. The learning process is not standardized or subject to scheduled lessons in which a predetermined curriculum is taught. With the beginning of formal schooling and enrollment in elementary school, however, the learning process becomes more standardized with formal instruction (i.e., a timetable) and a curriculum which predetermines the content to be learned within a specific time frame. Achievement feedback becomes increasingly focused on interindividual, social comparisons and entails long-term consequences for students’ school careers.

Besides such external factors resulting from the preschool setting, internal factors might also contribute to differences between the academic self-concepts of preschool children and school students. Internal factors address cognitive abilities for self-perceptions and self-evaluation including abstract thinking which are necessary for a realistic, abstract, and differentiated self-concept. However, such cognitive abilities are not yet established in preschool children but evolve as children get older (Harter, 1999).

External and internal factors might also interact leading to differences between the academic self-concepts of preschool children and school students. For example, the less differentiated self-concept of preschool children compared to school students might be attributed to both the lack of respective cognitive abilities and the undifferentiated educational context experienced in preschool years. In school years, self-concept might then become more differentiated because of the formation of necessary abilities as well as the experience of separate school subjects (Harter, 1999; Marsh, 1989; Marsh & Ayotte, 2003; Shavelson et al., 1976). Moreover, social comparison processes are known to be an important determinant of academic self-concept (Möller et al., 2009), but preschool children apply social comparison processes for the purpose of self-evaluation to a lesser extent than older students (Ruble, Boggiano, Feldman, & Loebl, 1980; Stipek & MacIver, 1989). This finding can be explained by lacking necessary cognitive abilities and by environmental conditions which place a higher emphasis on intraindividual, temporal comparisons (Stipek & Daniels, 1988). The utilization of social comparison processes is then boosted in school years when children have formed respective cognitive abilities and are more likely faced with the use of these comparison processes at school, for example by the assignment of school grades.

In sum, many aspects suggest that the academic self-concept of preschool children might differ from that of school students. Nonetheless, so far most of the studies on academic self-concept have been conducted with elementary and secondary school students and only little research has been done with preschool children. The present study addresses this research gap and focuses on a set of research questions regarding preschool children's math self-concept as one facet of academic self-concept (Möller et al., 2009) including its within-structure, achievement relations, and gender differences.

The Structure of Preschool Children's Academic Self-concept

In contemporary self-concept research and theory, academic self-concept is conceptualized as a domain-specific construct consisting of separate facets for math and verbal self-concepts (Marsh, 1990; Möller et al., 2009). This finding seems to also apply to preschool children as Marsh, Ellis, and Craven (2002) showed that four-year old and five-year-old preschool children differentiate between math and verbal self-concepts. However, so far, it has remained unclear whether preschool children also demonstrate a distinction between competence and affect components within domain-specific self-concepts as has been found in elementary and secondary school students (Arens et al., 2011; Marsh, Craven, et al., 1999; Marsh et al., 2013; Pinxten et al., 2014).

Self-concept has been assumed to become more differentiated as students grow older (Marsh, 1989; Marsh & Ayotte, 2003; Shavelson et al., 1976). Hence, young children might not yet be able to distinguish between competence and affect components within domain-specific academic self-concepts. Findings from studies with elementary school students provide some support for this conjecture. Chapman and Tunmer (1995) demonstrated that the correlations between students' competence perceptions in reading and attitudes toward reading decreased from grades 1 to 3, implying that the ability to differentiate between competence and affect self-perceptions is more pronounced in older than younger students. Similarly, in a sample of German students attending grades 1 to 4, the correlation between school-related motivation and competence beliefs was lower for the older students (Spinath & Spinath, 2005; see also Obach, 2003). Hence, although some findings indicate that younger children show a less pronounced differentiation between competence and affect components, research is so far restricted to elementary school students experiencing formal schooling, and should thus be extended to preschool children in non-formal settings.

Relations between Self-Concept and Achievement in Preschool Children

Considering self-concept–achievement relations, studies suggest that these relations are relatively weak in young children and increase with age (Chapman & Tunmer, 1995, 1997; Marsh, Ellis, et al., 2002). This finding also supports the notion that young children display an overly optimistic and unrealistic self-concept which is not strongly linked to objective achievement indicators (Nicholls, 1979; Stipek & Maclver, 1989; Wigfield, 1994). For example, Chapman and Tunmer (1997) reported a nonsignificant correlation of $r = .11$ between reading self-concept and early reading skills for five-year old children in New Zealand who had just started formal schooling. Herbert and Stipek (2005) found that self-ratings of literacy competence were significantly but not highly related to verbal achievement ($r = .22$) in a sample of first-grade students and six-year-old kindergarten children just before school enrollment. Self-ratings of math competence also showed a significant but low relation to math achievement ($r = .17$). For four-year-old and five-year-old preschool children, Marsh, Ellis, et al. (2002) reported a low correlation ($r = .15$) between self-concept and achievement in the verbal domain but a higher relation in the math domain ($r = .40$).

Considering the causal ordering in the relation between self-concept and achievement, meta-analyses have indicated the generalizability of the REM across age (Huang, 2011; Möller et al., 2009; Valentine et al., 2004). However, most of the studies included in these meta-analyses used samples of secondary school students. With regard to elementary school students, the pattern of findings seems to be more ambiguous. Some studies demonstrated reciprocal relations between self-concept and achievement for elementary school students (Guay, Marsh, & Boivin, 2003; Muijs, 1997). Other research, however, indicates a developmental perspective suggesting that the direction of influence varies with students' age. The skill-development model (i.e., academic self-concept is an outcome of academic achievement) may predominate in early school years whereas reciprocal relations between self-concept and achievement might only occur later (Chapman & Tunmer, 1997; Chen et al., 2013; Helmke & van Aken, 1995; Skaalvik & Hagtvet, 1990; Skaalvik & Valas, 1999). With regard to preschool children, studies on the relation between academic self-concept and achievement have only been cross-sectional and could thus not investigate reciprocal effects between self-concept and achievement. Hence, the present investigation aims to examine longitudinal relations between math self-concept and early math achievement across preschool years. Thereby, this study responds to limitations in existing research on the REM noted by Marsh, Byrne, and Yeung (1999) who articulated the need for further research on the longitudinal relations between self-concept and achievement in young children.

In elementary and secondary school, achievement can be measured by both standardized achievement test scores and school grades. Reciprocal effects between self-concept and achievement could be demonstrated for both kinds of achievement indicators (Helmke & van Aken, 1995; Marsh, Trautwein, et al., 2005; Marsh & Yeung, 1998; Möller, Zimmermann, & Köller, 2014). Since preschool children have not yet entered the formal school system, an alternative achievement indicator has to be used. Preschool children's achievement might be meaningfully operationalized by children's early skills in specific domains which have been demonstrated to be relevant precursors for later school achievement (Furnes & Samuelsson, 2011; Krajewski & Schneider, 2009a, 2009b; Preßler, Krajewski & Hasselhorn, 2013). Therefore, a special characteristic of investigating the relation between self-concept and achievement in preschool children refers to the application of an alternative achievement indicator (i.e., students' early or precursor skills).

Gender Differences in Preschool Children's Academic Self-concept

Gender differences in academic self-concept facets following gender stereotypes seem to already exist in elementary school years (Fredricks & Eccles, 2002; Jacobs et al., 2002; Wigfield et al., 1997). Findings with younger children are, however, more ambiguous and implicate that gender differences in academic self-concept evolve in early childhood to be in place soon after the beginning of formal schooling. For example, in a longitudinal study, Herbert and Stipek (2005) found that boys and girls did not differ in their levels of math self-concept when they were six years old and attended kindergarten or the first grade of elementary school. However, when the same children attended grades 3 and 5, their math self-concept followed a gender-stereotypic pattern with boys displaying higher levels. In a multicohort-multioccasion study, Marsh, Craven, and Debus (1998) found that the size of gender differences in math self-concept increased between 5 and 8 years of age. These studies, however, did not consider multiple measurement points during preschool years and thus cannot gain insight into the onset and developmental trajectory of gender differences in math self-concept during this time. By considering three measurements points during preschool years, the present study thus investigates more clearly how gender differences in math self-concept evolve and change across preschool years.

Besides testing gender differences in the mean level of math self-concept in the preschool years, this study also examines whether boys and girls differ in their relations between math self-concept and math achievement. Respective previous studies (Helmke & van Aken, 1995; Marsh, Trautwein, et al., 2005; Marsh & Yeung, 1998; Valentine et al., 2004) demonstrated gender-invariant relations, but this finding has to be expanded to preschool children.

The Present Study

The present investigation is based on a longitudinal study in which math self-concept and early math skills (labeled early math achievement in the following) were measured three times across preschool years. The aims were to (1) investigate whether preschoolers' math self-concept can be differentiated into competence and affect components, (2) examine the cross-sectional and longitudinal relations between math self-concept and early math achievement, and (3) study gender differences in the mean level of math self-concept and in the relation between math self-concept and early math achievement. In pursuit of these aims, the present study contributes to extending the understanding of math self-concept in preschool children.

Method

Participants

This study is a longitudinal study consisting of three measurement waves conducted with German preschool children. The first measurement wave (T1) was realized with a sample of 420 preschool children (48.8% girls; 51.2% boys) in spring 2008 when the children were in the next to last year before entering school and had an average age of 58.48 months (*SD* = 4.28). Time 2 (T2) data were collected 6 months later in autumn 2008 when children were on average 64.41 months old (*SD* = 3.99). Out of the T1 sample, 372 children (49.19% girls, 50.81% boys) participated at T2 indicating an attrition rate of 11.43%. At Time 3 (T3) in early summer 2009, the participating children (*N* = 244; 47.13% girls; 52.87% boys; attrition rate from T1: 34.05%) had an average age of 73.55 months (*SD* = 4.77) and were about to enter elementary school after the summer holidays. The children attended a total of 65 different public kindergartens all located in the southern part of Germany.

Materials and Procedure

The study is based on data that were collected in the context of the longitudinal project "The mature school child (Schulreifes Kind)" investigating German children's school readiness. The project was funded by the Ministry for Culture, Youth and Sports of the German federal state of Baden-Wuerttemberg and conducted in cooperation of the German Institute for International Educational Research, the university of Würzburg, and the university of Heidelberg. At each of the three measurement points, the participating children were tested individually during their regular kindergarten attendance. Research assistants, primarily masters students of psychology or education, were made familiar with the testing and scoring procedures in several training sessions beforehand. The testing procedures were administered in a separate room in the children's kindergarten during the morning hours to ensure that the children were concentrated. In order to make the testing procedure as comfortable as possible for the children and to adapt it to preschool children's motivation, endurance, and attention capacity, the complete testing procedure was split into separate sessions taking place on successive days. On the first day, the self-concept measure was administered, and the math achievement test (and other measures on children's school readiness, e.g., memory retention, fine-motoric skills) was implemented on the following days. Parental consent was obtained for each child.

Math self-concept. For measuring math self-concept, the original math self-concept scale of the Self Description Questionnaire for Preschoolers (SDQP; Marsh, Ellis, et al., 2002) was translated into German using a forward-backward translation with the help of a native English speaker. The SDQP has been found to be a psychometrically sound measure to assess multiple self-concept facets of preschool children. The math self-concept scale consists of six items. Among these six items, four items refer to students' self-evaluation of math competence (e.g., "Are you good at counting?") whereas two items ask for children's motivational-affect responses towards math (e.g., "Do you like saying numbers?"; see Table 2 for the wordings and standardized factor loadings of all items and Table 4 for the descriptive statistics of the measures used).

Given the preschool children's lack of reading and writing skills, the SDQP was individually administered applying the individual-interview style recommended by Marsh, Ellis, et al. (2002; see also Marsh, Craven, & Debus, 1991). The items were worded as questions, and the children had to answer in a stepwise procedure. Based on a double binary response format, the children were first asked whether they would respond "yes" or "no" to each question. In a second step, the children should specify their responses to "yes, always" or "yes, sometimes" if they had responded "yes", or to specify "no, always" or "no, sometimes" if their initial answer was "no". Thus, there were ultimately four options for the children to respond to a specific item (no, always – no, sometimes – yes, sometimes – yes, always). These answers were coded from 0 to 3 in order that higher values reflected higher levels of math self-concept.

The reliability of the SDQP math self-concept scales was investigated by estimates of scale reliability (ρ; also labeled composite or instrument reliability), as a reliability estimate which has been explicitly developed within the framework of structural equation modeling (SEM; Raykov, 2009). The resulting coefficients were marginal for the self-concept scales at each measurement point when treating the competence-related and affect-related items as separate scales: Competence component: T1: $\rho = .552$; T2: $\rho = .540$; T3: $\rho = .504$; affect component: T1: $\rho = .594$, T2: $\rho = .581$; T3: $\rho = .543$. However, these reliability estimates are deemed sufficient for latent modeling in SEM correcting for measurement error (Raines-Eudy, 2000). They also match previous findings revealing low reliability estimates for self-concept scales in young children (Marsh et al., 1991; Marsh, Debus, & Bornholt, 2005), and meet the guidelines proposed by some studies (Raines-Eudy, 2000) according to which values above .50 are considered acceptable for new scales.

Early math achievement. Math achievement was operationalized as early quantity-number skills. For this purpose, three tasks were used which were taken from a broader pool of tasks measuring children's early quantity-number skills as applied in the studies of Krajewski and Schneider (2009a, 2009b). Supporting their validity, these tasks were found to predict math achievement at the end of grades 3 and 4 in elementary school (Krajewski & Schneider (2009a, 2009b). The same set of tasks was applied at each measurement point. First, the children were asked to count forward as long as possible in the correct sequence. Afterwards, the children had to count backwards starting from 5. In addition, they should name the succeeding and preceding numbers of given numbers. The second task required the children to name numbers. Arabic numerals ranging from 1 to 10 were presented to the children in random order and the children were asked to name the shown number. The third task refers to children's ability of linking quantities and numbers. The children were given a card showing a specific number and were asked to correctly match it to a picture that shows the respective amount of objects and vice versa. For example, a picture showing three dots should be matched to a card depicting the respective Arabic numeral. Therefore, the tasks used in the present study cover a range of basic and higher-order early math skills. Children's accomplishments on the different math tasks were rated according to pre-specified guidelines which defined the scores the children got for a specific answer (Krajewski & Schneider, 2009a, 2009b; Preßler et al., 2013). The highest achievable score was 7 for the first task and 5 for tasks two and three. Estimates of scale reliability demonstrated adequate internal consistencies of early math achievement at each measurement point: T1: ρ =.808; T2: ρ = .777; T3: ρ = .545.

Statistical Analyses

We first conducted CFA models in order to examine whether preschool children's math self-concept can be differentiated into competence and affect components. We therefore stated a CFA model (Model 1 in Table 1) in which math self-concept was conceptualized as a global factor at all three measurement points. In other words, for each measurement point, we assumed a global math self-concept factor defined by all six items of the SDQP math self-concept scale completed by the children at the respective measurement point. Hence, these three global math self-concept factors (one factor for T1, T2, and T3, respectively) were estimated by both the four competence-related and the two affect-related items rated by the children at each measurement point. We then tested a model assuming separate factors for math competence and math affect at each measurement point. Hence, this model (Model 2 in Table 1) consists of six separate factors: One factor for the competence component of math self-concept at T1, T2, and T3, respectively, and one factor for the affect component of math self-concept at T1, T2, and T3, respectively. The math competence self-concept factors were defined by the four competence-related items and the math affect self-concept factors were defined by the two affect-related items of the SDQP math self-concept scales used at each measurement point.

The second research question addresses the cross-sectional and longitudinal relations between early math achievement and math self-concept. For this purpose, we added three (i.e., one for each measurement point) factors for early math achievement to the factors for math competence self-concept and math affect self-concept. The math achievement factors of each measurement point were defined by the scores the children obtained in the three math tasks completed at the respective measurement points. This model (Model 3 in Table 1) thus consists of separate factors for math competence self-concept, math affect self-concept, and early math achievement for each of the three measurement points (i.e., 9 factors in total) and allows insights into the relations among these factors.

Following the methodological approaches realized in previous studies on the REM (Marsh, Byrne, et al., 1999; Marsh, Trautwein, et al., 2005; Möller et al., 2011; Niepel et al., 2014), cross-lagged panel models conducted in the SEM approach were applied in order to examine longitudinal relations between math self-concept and early math achievement (Models 4 and 5 in Table 1). Cross-lagged panel models include cross-lagged paths depicting reciprocal relations between one variable and another between two consecutive measurement points while simultaneously taking the stability of the constructs into account (Curran & Bollen, 2001). Therefore, cross-lagged panel models also include autoregressive or stability paths estimating the effect of one variable on the same variable across subsequent time waves. Thus, depicting the stability of math self-concept (early math achievement), Models 4 and 5 estimated the relation between math self-concept (early math achievement) measured at T1 and T2, and the relation between math self-concept (early math achievement) measured at T2 and T3. In addition, these models estimated the cross-paths leading from math self-concept at T1 (T2) to early math achievement at T2 (T3), and the cross-paths leading from early math achievement at T1 (T2) to math self-concept at T2 (T3) (Figure 1).

The third research question targets gender differences in the mean levels and relations between early math achievement and math self-concept. To this aim, we stated various invariance models including students' gender as a grouping variable (Models 6-11 in Table 1; Meredith, 1993; Millsap, 2011). We started with a model of configural invariance (Model 6) in which the same factor pattern was assumed across gender. Thus, the same number of factors (separate factors for math competence, math affect, and math achievement at T1, T2, and T3, respectively) was assumed for boys and girls but the factor loadings and item intercepts were freely estimated in both groups. We then proceeded to a series of restricted models in which certain model parameters were constrained to be of equal size for boys and girls. In this context, we stated a model of factor loading invariance (Model 7, also known as weak measurement invariance; Meredith, 1993). The invariance of factor loadings is conceptualized as the most important invariance model as it is a prerequisite for all further invariance models. The next model (Model 8) assuming both invariant factor loadings and item intercepts across gender (also known as strong measurement invariance; Meredith, 1993) forms the basis for examining gender differences in factor means. Model 9 included equal-sized factor variances for boys and girls. In the case of invariant factor variances, invariance of factor correlations can be tested by probing the invariance of factor covariances (Marsh, 1994). Hence, Model 10 additionally integrated equality constraints on the factor covariances and thus served to examine whether boys and girls differed in their relations between the self-concept and achievement factors. Model 11 further included invariant means for the self-concept and achievement factors for boys and girls at all three measurement points. This model aids to get insight into gender differences in the mean levels of math self-concept (with its competence and affect components) and early math achievement.

The analyses were conducted with *Mplus* Version 7.0 (Muthén & Muthén, 1998-2012) using the maximum likelihood estimator with robust standard errors and fit statistics (i.e., the MLR option in Mplus). All models integrated correlated uniquenesses between the same items used at each measurement point to measure the math self-concept and math achievement factors to consider the shared method variance when repeatedly using the same indicators to infer a construct (Marsh & Hau, 1996; Marsh et al., 2013). For evaluating the fit of the latent models, we present the chi-square statistic with its degrees of freedom representing the discrepancy between the model implied and the observed sample covariance matrices. However, due to its dependency on sample size (Marsh, Hau, & Grayson, 2005), researchers are advised not to use the chi-square statistic as the ultimate criterion for evaluating model fit but should rather consider a variety of descriptive goodness-of-fit indicators (Marsh, Hau, & Wen, 2004). Here, we present the comparative fit index (CFI), the Tucker-Lewis index (TLI), the root mean square error of approximation (RMSEA) including its confidence interval, and the standardized root mean square residual (SRMR). For the CFI and TLI, values above .90 indicate an adequate model fit, while values above .95 are seen as an indication of good model fit (Hu & Bentler, 1999). For the RMSEA, values should be below .05 in order to represent a close fit, and values between .05 and .08 indicate a reasonable fit (Browne & Cudeck, 1993). Regarding the SRMR, values below .08 refer to a good model fit.

The various invariance models used to test gender differences can be conceptualized as nested models which only differ in the model parameters stated to be equal across gender groups. In consequence, the chi-square difference test can be applied to evaluate whether the assumption of invariance can be maintained. However, similar to the chi-square value as an indicator of model fit, the chi-square difference test has been found to be sensitive to sample size (Marsh, Hau, et al., 2005). Thus, researchers are advised to base their judgement of invariance on the observation of changes in the descriptive goodness-of-fit indices. Here, we follow the guidelines of Cheung and Rensvold (2002) suggesting that invariance can be asserted as long as the CFI does not drop more than .01 between more and less restrictive models.

Missing data were estimated using the full maximum likelihood estimator (FIML) implemented in Mplus. FIML takes into account information from all participants at all measurement points included and has been demonstrated to provide more efficient and less biased estimates than listwise deletion or mean imputation even when there is a high amount of missing data (Graham, 2009). The FIML method is furthermore accepted as an appropriate means of accounting for missing data in longitudinal studies (Jeličič, Phelps, & Lerner, 2009) and it has been successfully applied in other longitudinal studies on students' self-concept (Pinxten et al., 2014; Trautwein, Lüdtke, Köller, & Baumert, 2006). Additional t-tests demonstrated that children missing at T2 or T3 did not differ from children participating at all measurement points regarding the mean levels of math competence self-concept, math affect self-concept, and early math achievement measured at T1.

Results

Differentiation between Competence and Affect Components

Model 1 (see Table 1) assuming global math self-concept factors at each measurement point incorporating both competence-related and affect-related items showed a satisfactory level of fit. However, the significant chi-square difference test for MLR estimation [$\chi^2_{diff}(12) = 43.78$, $p < .001$] and the improved descriptive goodness-of-fit indices indicated a better fit for the 2-factor model assuming separate factors for competence and affect components of math self-concept at each measurement point (Model 2). Given the positive standardized factor loadings emanating from this model, the factors for math competence self-concept (T1: $M = .506$; T2: $M = .494$; T3: $M = .442$) and math affect self-concept (T1: $M = .653$; T2: $M = .684$; T3: $M = .607$) were all well-defined (see Table 2). The competence and affect components of math self-concept were substantially but not perfectly correlated at each measurement point and the correlation was found to decrease from T1 to T3 (T1: $r = .891$; T2: $r = .696$; T3: $r = .688$, all $p < .001$).

Relations between Math Self-concept and Math Achievement

Cross-sectional relations. In order to test the relations between math self-concept and early math achievement, we integrated the math achievement factors for each measurement point in Model 2 leading to Model 3. The results demonstrated that the correlation between early math achievement and the competence component of math self-concept increased across age (T1: $r = .402$; T2: $r = .418$; T3: $r = .532$, all $p < .001$). At each measurement point, the correlation between early math achievement and the competence component of math self-concept was descriptively higher than the correlation between early math achievement and the affect component of math self-concept (T1: $r = .123$, *ns*; T2: $r = .075$, *ns*, T3: $r = .242$, $p < .05$; see Table 3).

Longitudinal relations. Given the high correlation between the competence and affect components of math self-concept in Model 3 (T1: $r = .882$; T2: $r = .715$; T3: $r = .677$, all $p < .001$), cross-lagged panel models integrating both components of math self-concept might result in multicollinearity and thus in untrustworthy coefficients (Marsh, Dowson, Pietsch, & Walker, 2004). Therefore, we continued our analyses by studying longitudinal relations between math self-concept and early math achievement separately for the competence (Model 4) and affect (Model 5) components of math self-concept. Model 4 including the competence component of math self-concept displayed high stability estimates for early math achievement (T1-T2: $\beta = .901$, $p < .001$; T2-T3: $\beta = .839$, $p < .001$) and lower, yet statistical significant stability estimates for math competence self-concept (T1-T2: $\beta = .457$, $p < .001$; T2-T3: $\beta = .350$, $p < .01$). Early math achievement was found to be significantly related to math competence self-concept across T1 and T2 ($\beta = .242$, $p < .01$) and across T2 and T3 ($\beta = .340$, $p < .01$). The competence component of math self-concept was not associated with later math achievement across T1 and T2 and across T2 and T3 (see Table 5 and Figure 1).

Model 5 tested the longitudinal relations between the affect component of math self-concept and early math achievement. The findings only demonstrated stability of the constructs (math affect self-concept: T1-T2: $\beta = .377$, $p < .01$; T2-T3: $\beta = .538$, $p < .001$;

early math achievement: T1-T2: $\beta = .915$, $p < .001$; T2-T3: $\beta = .839$, $p < .001$) but did not show any relations across constructs. In other words, prior math achievement was not found to be related to subsequent math affect self-concept and prior math affect self-concept did not demonstrate any associations with later math achievement (see Table 5 and Figure 1).

Gender Invariance

The inspection of the various models testing gender invariance (Models 6 to 11) indicates factor loading invariance since the decrease in the CFI value (ΔCFI = .003) between the model of configural invariance (Model 6) and the model of invariant factor loadings (Model 7) did not exceed the guideline of ΔCFI = .01 proposed by Cheung and Rensvold (2002) for rejecting invariance. Hence, the factors seem to have the same meanings for preschool boys and girls. The findings also supported the invariance of item intercepts as the CFI displayed only a slight decrease (ΔCFI = .002) between Models 7 and 8 allowing meaningful latent mean level comparisons. We continued the invariance tests by Model 9 that additionally included invariant variances of the math self-concept (including the competence and affect components) and math achievement factors across gender. Given that the CFI remained stable, invariant factor variances across gender could be seen as established. Hence, models of invariant factor covariances could be conducted in order to test the invariance of factor correlations (Marsh, 1994). In Model 10, the covariances between the factors for math achievement, math competence self-concept, and math affect self-concept were thus constrained to invariance across gender. Due to the small decrease in the CFI value (ΔCFI = .004), similar relations between math achievement and the math self-concept factors (with both the competence and affect components) can be assumed for boys and girls.

The research question regarding mean level differences was addressed by Model 11 which included gender-invariant means for the math achievement, math competence self-concept, and math affect self-concept factors at each measurement point. Given the marginal decline of ΔCFI = .003 relative to the less restrictive Model 10, the results indicated equal-sized mean levels for boys and girls. This finding was further supported by an inspection of the model parameters resulting from Model 8 in which both the factor loadings and item intercepts were stated to be invariant across gender. In this model, for model identification purposes, the factor means were constrained to be zero in the first group (girls in our case) serving as a reference group and freely estimated in the other group (i.e., boys). Hence, the mean level estimates of the comparison group depict the deviations (in *SD* units) from the reference group. Boys and girls were not found to differ in their mean levels of the competence and affect components of math self-concept at all three measurement points. With respect to early math achievement, boys were found to display higher levels at T2 (expressed in SD units: .336, $p < .05$), but not at T1 and T3 (also see Table 4).

Discussion

Research on academic self-concept has primarily focused on elementary and secondary school students. By focusing on the math self-concept of German preschool children including its structure, achievement relations, and gender differences, this study aimed to contribute to and extend the knowledge on preschool children's academic self-concept.

Differentiation between Competence and Affect Components

With regard to the structure of math self-concept, the examination of the CFA model fits revealed evidence of the separation between competence and affect components of math self-concept in preschool children. Furthermore, the competence and affect components were highly but not perfectly correlated at each measurement point. However, at the first measurement point, the correlation between the competence and affect components was very high so that the distinctiveness of both components might be questioned. Given that the correlation was found to decrease with students' age, there is thus some evidence of an increasing differentiation between competence and affect perceptions in preschool children's math self-concept. The differentiation process seems to occur in early and middle preschool years as the differentiation between competence and affect components of math self-concept was found to be in place at the second and third measurement points. Thus, our findings suggest that it seems appropriate to distinguish between children's competence self-perceptions and affective-motivational responses with respect to academic domains at least one year before the beginning of formal schooling (i.e., the second and third measurement points of this study). Along with the previous finding of preschool children's differentiation between math and verbal self-concepts (Marsh, Ellis, et al., 2002), the current state of research indicates that preschool children's academic self-concept is more differentiated than originally assumed (Harter, 1999; Shavelson et al., 1976). Overall, the generalizability of the competence-affect separation of math self-concept seem to be generalizable across preschool children (this study), elementary school students (Arens et al., 2011), and secondary school students (Marsh et al., 2013).

For researchers and practitioners it is thus inadequate to assume a perfect match between competence and affect self-perceptions in preschool children. Stated otherwise, researchers and practitioners should not presume that preschool children like the domains they are good at and that they are competent in the domains they like. Researchers and practitioners are rather advised to consider that academic self-concept is already differentiated in preschool children. In self-concept measurement practice, separate scales should be used for assessing young children's competence and affect self-perceptions, and competence-related and affect-related items should not be combined into unified scales. Furthermore, preschool children's multiple self-concept facets might be differentially affected by environmental experiences and interventions. Instead of assuming that self-concept interventions generally enhance preschool children's self-concept, researchers and practitioners should take into account that intervention effects might be restricted to some self-concept facets and may thus influence the competence and affect components of math self-concept in different ways. This conclusion underlines the guideline that intervention programs should be specifically tailored to the target facets which are intended to be focused and enhanced (Craven, Marsh, & Burnett, 2003; O'Mara, Marsh, Craven, & Debus, 2006). Administration of adequate feedback including internally focused performance feedback and attributional feedback (Craven, Marsh, & Debus, 1991) might enhance the competence component of academic self-concept. The affect component of math self-concept might in turn benefit from value-related intervention approaches (Hulleman, Godes, Hendricks, & Harackiewicz, 2010).

Relations between Math Self-concept and Math Achievement

The notion that even preschool children distinguish between competence and affect components within math self-concept is further substantiated by the observation that both components shared differential relations with achievement. In the cross-sectional analyses, the competence component of math self-concept revealed descriptively higher relations to early math achievement compared to the affect component. This finding was corroborated by the longitudinal analyses which disclosed that the competence but not the affect component was significantly related to subsequent math achievement measures (see below). These results of differential achievement relations of the competence and affect components of academic self-concept replicated previous findings with elementary and secondary school students (Arens et al., 2011; Marsh et al., 2013; Pinxten et al., 2014).

This study also demonstrated that the strength of the relation between the competence component of math self-concept and early math achievement increased with students' age. This finding corresponds to the assumption that young children are characterized by overly positive competence self-concepts which increasingly become more realistic and more highly related to objective outcome criteria (Nicholls, 1979; Stipek & Maclver, 1989; Wigfield, 1994). Nonetheless, the correlation between the competence component of math self-concept and early math achievement showed a substantial size at each measurement point. This finding counters findings from previous studies (Chapman & Tunmer, 1995, 1997; Herbert &

Stipek, 2005; Marsh et al., 2002) which demonstrated only low self-concept–achievement relations in young children. These divergent findings might originate from different methodologies used. For instance, the present study considered latent correlations among constructs leading to higher relations due to the correction for measurement error. In addition, instruments applied to measure preschool children's academic self-concept and achievement might differ between studies. Moreover, given the variety of preschool institutions and systems (see below), disparities in the results might originate from differences in children's learning experiences and environments.

In the longitudinal analyses, former levels of early math achievement were found to be significantly related to later levels of the competence component of math self-concept, while there were no significant relations between former competence components of math self-concept and later measures of early math achievement. When considering the affect component of math self-concept, no significant relations were found between former affect math self-concept and later math achievement and between former math achievement and later affect math self-concept. These findings do not only support the separation between competence and affect components in preschool children's math self-concept (see above) but also bear important insights into the application of the REM to preschool children. The results imply that the relation between math self-concept and early forms of math achievement is primarily unidirectional instead of reciprocal in the preschool years. This unidirectional relation is a relation between prior achievement and subsequent competence self-concept indicating the appropriateness of the skill-development model in preschool years. Thereby, the conclusion of this study corresponds to previous studies suggesting developmental changes in the relation between self-concept and achievement. Reciprocal relations might only emerge in later years while unidirectional effects from achievement to self-concept might predominate in younger children (Chapman & Tunmer, 1997; Chen et al., 2013; Helmke & van Aken, 1995; Skaalvik & Hagtvet, 1990; Skaalvik & Valas, 1999). This presumption is quite plausible as preschool children might have not yet established a sufficiently stable self-concept, which is a prerequisite for influencing later achievement (Wigfield & Karpathian, 1991).

Practically, the found predominance of relations between former levels of early achievement and later self-concept argues for an emphasis on skill development during preschool years. Nevertheless, research and theory should also explore effective approaches to self-concept enhancement in early years. Given that a positive self-concept is an aim in itself and has been found to impact upon achievement in later school years (Huang, 2011; Marsh & Craven, 2006; Valentine et al., 2004), the formation of a positive self-concept should be of high concern throughout development.

Moreover, the present finding of relations between former math achievement and subsequent math competence self-concept warrants consideration because math achievement was operationalized as early quantity-number skills. Correspondingly, early academic skills do not seem to have implications only for students’ cognitive development (Furnes & Samuelsson, 2011; Krajewski & Schneider, 2009a, 2009b; Preßler et al., 2013), but also for the formation of non-cognitive determinants of students’ achievement including competence self-perceptions. Consequently, research and practice should cooperatively search for effective means to foster preschool children’s early academic skills, in order to facilitate preschool children’s learning in cognitive and non-cognitive terms and to improve school readiness. Attempts to enhance preschool children’s early academic skills encompass both domain-specific approaches (e.g., fostering children’s early math skills; Howes et al., 2008; Starkey, Klein, & Wakeley, 2004) and domain-general approaches (e.g., facilitating children’s attention, working memory, inhibitory control, or behavioral regulation; McClelland et al., 2007). These approaches should be examined and optimized regarding their influence on the development of children’s cognitive and non-cognitive educational outcomes.

Gender Invariance

Invariance tests demonstrated similar relations between early math achievement and math self-concept, including both its competence and affect components for preschool boys and girls. Similar results have also been found for elementary school students (Helmke & van Aken, 1995) and secondary school students (Marsh, Trautwein, et al., 2005; Marsh & Yeung, 1998). Hence, gender-invariant relations between academic self-concept and academic achievement seem to exist irrespective of age (see also Möller et al., 2009; Valentine et al., 2004 for meta-analytic results).

In addition, boys and girls were not found to differ in their mean levels of the competence and affect components of math self-concept. This finding is noteworthy given the consistent finding that boys display higher mean levels of math self-concept even in early elementary school years (Fredricks & Eccles, 2002; Jacobs et al., 2002; Marsh, 1989; Skaalvik & Skaalvik, 2004; Wilgenbusch & Merrell, 1999). Hence, this finding indicates that gender differences in self-concept facets evolve in the late preschool years (Herbert & Stipek, 2005; Marsh et al., 1998; Marsh et al., 2002). In this regard, it might be interesting to learn more about the timing and determining factors of the emergence of gender differences in math self-concept which might also vary contingent upon environmental factors such as parents' or teachers' beliefs (Jacobs & Eccles, 1992; Tiedemann, 2000). Respective knowledge might be helpful for researchers and practitioners, since it might be more effective to implement interventions to enhance girls' competence perceptions and affective reactions towards math at a point in time when girls' math self-concept is not yet dominated by a gender-stereotypic pattern.

Strengths, Limitations, and Future Research

The present study focused on different research questions which had already been extensively investigated with elementary and secondary school students, thus linking the present study to contemporary self-concept research and theory. Given the so far sparse findings on preschool children's self-concept, this study therefore provides practitioners with new and interesting insights into the math self-concept of preschool children and makes a substantial contribution to self-concept research and theory.

Despite its strengths, this study faces some shortcomings stimulating future research. The items applied to measure preschool children's math self-concept were adopted from the SDQP as a well-established instrument (Marsh, Ellis et al., 2002). However, the German translation seems to suffer from some limitations. First, the scales for measuring the competence component and affect component of math self-concept revealed marginal reliability estimates. This may have resulted from the shortness of the scales (4 items for the competence component of math self-concept; 2 items for the affect component of math self-concept). Alternatively, it may reflect a more general problem regarding self-concept measurement with young children since other studies also reported low reliability estimates of self-concept measures administered to young children (Marsh, Debus, et al., 2005). Given that the present analyses relied on latent analyses correcting for the unreliability of the used scales, the main conclusions may not be negatively influenced by the marginal reliability estimates. Nonetheless, the low reliability estimates should be borne in mind when using the scales as manifest measures. Second, the factor loadings and reliability estimates decreased across the three measurement waves although previous studies found that psychometric properties of self-concept measures improve with students' age (Marsh, Debus, et al., 2005). Finally, the factor loadings of the item "Are you good at telling the time?" for measuring the competence component of math self-concept were very small at all three measurement points. This item does not seem to be a reliable indicator for preschool children's math competence self-concept, maybe because it is not so closely linked to the math domain which is primarily associated with numbers, figures, and shapes. Despite these obvious limitations of the math self-concept scale applied, the scale seems to be of sufficient psychometric properties for application in the present study. The validity of the math self-concept scale could be strongly supported in the present study itself given the found relations to early math achievement.

Nonetheless, research and practice face the challenge of improving ways to measure preschool students’ math self-concept including the competence and affect components.

With respect to the investigation of presumptive reciprocal effects between math self-concept and early math achievement, the inflated stability of the measure for early math achievement across the three measurement waves might have prevented math self-concept from being substantially related to math achievement at later waves in addition to prior math achievement. Hence, studies with longer time intervals between the different measurement waves would be useful. In addition, since the same math tasks were used at each measurement point, it would be worthwhile to apply different tasks at each measurement point connected by anchor items or to use alternative indicators of early math achievement than applied in this study.

Bearing in mind that this study was conducted with German preschool children, caution should be made in transferring the present findings to preschool children in other countries. Preschool systems vary strongly across countries and cultures with differences in their structure (e. g., age range, curriculum, composition) and content (i.e., quality of programs, education emphasis; Boocock, 1995; Burger, 2010; Camilli, Vargas, Ryan & Barnett, 2010; Cryer, Tietze, Burchinal, Leal, & Palacios, 1999). Since children’s environment has been conceptualized as an important determinant of self-concept (Shavelson et al., 1976), different preschool environments might have differential impact on children’s self-concept. Thus, further studies should integrate children before the onset of formal schooling from a wider range of countries and cultures.

This study had a sophisticated study design as it covered three measurement waves across students’ preschool years. However, it only started when the children were in the next to last year before entering school. Future longitudinal studies might benefit from considering an even larger time span. Since the findings of this study indicated an increasing differentiation between competence and affect perceptions in preschool children’s math self-concept, earlier measurement points directly after children's enrollment in preschool would be useful. It would also be interesting to include later measurement points after students' transition to elementary school to track variations in the differentiation between competence and affect components of domain-specific academic self-concepts. Finally, since the present study only focused on the math domain, further studies are needed to explore the generalizability of our findings to other academic domains. Given the high domain specificity of academic self-concept with separate math and verbal facets (Marsh, 1990; Möller et al., 2009), the findings for math self-concept may not apply to verbal self-concept. For example, Marsh, Ellis, et al. (2002) found only a low correlation between verbal self-concept and early verbal achievement but a moderate relation between math self-concept and early math achievement in their sample of four-year-old and five-year-old children. Thus, researchers and practitioners might benefit from the knowledge about preschool children's academic self-concept that emerged from this study but may also take it as a starting point and inspiration for future research.

References

Arens, A.K., & Hasselhorn, M. (2015). Differentiation of competence and affect self-perceptions in elementary school students: Extending empirical evidence. *European Journal of Psychology of Education, 30,* 405-419. doi: 10.1007/s10212-015-0247-8

Arens, A.K., Yeung, A.S., Craven, R.G., & Hasselhorn, M. (2011). The twofold multidimensionality of academic self-concept: Domain specificity and separation between competence and affect components. *Journal of Educational Psychology, 103*, 970-981. doi: 10.1037/a0025047

Boocock, S.S. (1995). Early childhood programs in other nations: Goals and outcomes. *The Future of Children, 5*, 94-114. doi: 10.2307/1602369

Browne, M.W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K.A. Bollen & J.S. Long (Eds.), *Testing structural equation models* (pp. 136-162). Newbury Park, CA: Sage.

Burger, K. (2010). How does early childhood care and education affect cognitive development? An international review of the effects of early interventions for children from different social backgrounds. *Early Childhood Research Quarterly, 25*, 140-165. doi: 10.1016/j.ecresq.2009.11.001

Byrne, B.M. (1996). *Measuring self-concept across the life span: Issues and instrumentation.* Washington, DC: American Psychological Association.

Camilli, G., Vargas, S., Ryan, S., & Barnett, W.S. (2010). Meta-analysis of the effects of early education interventions on cognitive and social development. *Teachers College Record, 112*, 579-620.

Caslyn, R., & Kenny, D. (1977). Self-concept of ability and perceived evaluation by others: Cause or effect of academic achievement? *Journal of Educational Psychology, 69,* 136-145. doi: 10.1037/0022-0663.69.2.136

Chapman, J.W., & Tunmer, W.E. (1995). Development of young children's reading self-concepts: An examination of emerging subcomponents and their relationship with reading achievement. *Journal of Educational Psychology, 87*, 154-167. doi: 10.1037/0022-0663.87.1.154

Chapman, J.W., & Tunmer, W.E. (1997). A longitudinal study of beginning reading achievement and reading self-concept. *British Journal of Educational Psychology, 67,* 279-291. doi: 10.1111/j.2044-8279.1997.tb01244.x

Chen, S-K., Yeh, Y-C., Hwang, F-M., & Lin, S.S.J. (2013). The relationship between academic self-concept and achievement: A multicohort–multioccasion study. *Learning and Individual Differences, 23*, 172-178. doi:10.1016/j.lindif.2012.07.021

Cheung, G.W., & Rensvold, R.B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modeling, 9*, 233-255. doi:10.1207/S15328007SEM0902_5

Craven, R.G., Marsh, H.W., & Burnett, P. (2003). Cracking the self-concept enhancement conundrum. A call and blueprint for the next generation of self-concept enhancement research. In H.W. Marsh, R.G. Craven, & D.M. McInerney (Eds.), *International advances in self research: Speaking to the future* (pp. 91-126). Grennwich, CT: Information Age.

Craven, R.G., Marsh, H.W., & Debus, R.L. (1991). Effects of internally focused feedback and attributional feedback on the enhancement of academic self-concept. *Journal of Educational Psychology, 83*, 17-27. doi: 10.1037/0022-0663.83.1.17

Cryer, D., Tietze, W., Burchinal, M., Leal, T., & Palacios, J. (1999). Predicting process quality from structural quality in preschool programs: a cross-country comparison. *Early Childhood Research Quarterly, 14*, 339-361. doi:10.1016/S0885-2006(99)00017-4

Curran, P.J., & Bollen, K.A. (2001). The best of both worlds: Combining autoregressive and latent curve models. In L.M. Collins & A.G. Sayer (Eds.), *New methods for the analysis of change* (pp. 105-136). Washington, DC: American Psychological Association.

Eccles, J.S. & Wigfield, A. (1995). In the mind of the actor: The structure of adolescents' achievement task values and expectancy-related beliefs. *Personality and Social Psychology Bulletin, 21*, 215-225. doi: 10.1177/0146167295213003

Fredricks, J., & Eccles, J.S. (2002). Children's competence and value beliefs from childhood through adolescence: Growth trajectories in two male-sex-domains. *Developmental Psychology, 38*, 519-533. doi: 10.1037/0012-1649.38.4.519

Furnes, B., & Samuelsson, S. (2011). Phonological awareness and rapid automatized naming predicting early development in reading and spelling: Results from a cross-linguistic longitudinal study. *Learning and Individual Differences, 21*, 85-95. doi:10.1016/j.lindif.2010.10.005

Guay, F., Marsh, H.W., & Boivin, M. (2003). Academic self-concept and academic achievement: A developmental perspective on their causal ordering. *Journal of Educational Psychology, 95*, 124-136. doi: 10.1037/0022-0663.95.1.124

Harter, S. (1999). *The construction of the self. A developmental perspective*. New York: The Guilford.

Helmke, A., & van Aken, M.A.G. (1995). The causal ordering of academic achievement and self-concept of ability during elementary school: A longitudinal study. *Journal of Educational Psychology, 87*, 624-637. doi: 10.1037/0022-0663.87.4.624

Herbert, J., & Stipek, D. (2005). The emergence of gender differences in children's perceptions of their academic competence. *Journal of Applied Developmental Psychology, 26*, 276-295. doi:10.1016/j.appdev.2005.02.007

Howes, C., Burchinal, M., Pianta, R., Bryant, D., Early, D., Clifford, R., & Barbarin, O. (2008). Ready to learn? Children's pre-academic achievement in pre-Kindergarten programs. *Early Childhood Research Quarterly, 23,* 27-50. doi:10.1016/j.ecresq.2007.05.002

Hu, L., & Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1-55. doi:10.1080/10705519909540118

Huang, C. (2011). Self-concept and academic achievement: A meta-analysis of longitudinal relations. *Journal of School Psychology, 49*, 505-528. doi:10.1016/j.jsp.2011.07.001

Hulleman, C.S., Godes, O., Hendricks, B.L., & Harackiewicz, J.M. (2010). Enhancing interest and performance with a utility value intervention. *Journal of Educational Psychology, 102*, 880-895. doi: 10.1037/a0019506

Jacobs, J.S., & Eccles, J.S. (1992). The impact of mothers' gender-role stereotypic beliefs on mothers' and children's ability perceptions. *Journal of Personality and Social Psychology, 63*, 932-944. doi: 10.1037/0022-3514.63.6.932

Jacobs, J.E., Lanza, S., Osgood, W.D., Eccles, J.S., & Wigfield, A. (2002). Changes in children's self-competence and values: Gender and domain differences across grades one through twelve. *Child Development, 73*, 509-527. doi: 10.1111/1467-8624.00421

Jeličič, H., Phelps, E., & Lerner, R.M. (2009). Use of missing data methods in longitudinal studies: The persistence of bad practices in developmental psychology. *Developmental Psychology, 45*, 1195-1199. doi: 10.1037/a0015665

Krajewski, K., & Schneider, W. (2009a). Early development of quantity to number-word linkage as a precursor of mathematical school achievement and mathematical difficulties: Findings from a four-year longitudinal study. *Learning and Instruction, 19*, 513-526. doi:10.1016/j.learninstruc.2008.10.002

Krajewski, K., & Schneider, W. (2009b). Exploring the impact of phonological awareness, visual-spatial working memory, and preschool quantity-number competencies on mathematics achievement in elementary school: Findings from a 3-year- longitudinal study. *Journal of Experimental Child Psychology, 103*, 516-531. doi:10.1016/j.jecp.2009.03.009

Marsh, H.W. (1989). Age and sex effects in multiple dimensions of self-concept: Preadolescence to early-adulthood. *Journal of Educational Psychology, 81*, 417-430. doi: 10.1037/0022-0663.81.3.417

Marsh, H.W. (1990). The structure of academic self-concept: The Marsh/Shavelson model. *Journal of Educational Psychology, 82*, 623-636. doi: 10.1037/0022-0663.82.4.623

Marsh, H.W. (1993). The multidimensional structure of academic self-concept: Invariance over gender and age. *American Educational Research Journal, 30,* 841-860. doi: 10.3102/00028312030004841

Marsh, H.W. (1994). Confirmatory factor analysis models of factorial invariance: A multifaceted approach. *Structural Equation Modeling, 1*, 5-34. doi: 10.1080/10705519409539960

Marsh, H.W. (2007). *Self-concept theory, measurement and research into practice: The role of self-concept in educational psychology*. Leicester, UK: British Psychological Society.

Marsh, H.W., Abduljabbar, A.S., Abu-Hilal, M., Morin, A.J.S., Abdelfattah, F., Leung, K.C., … & Parker, P. (2013). Factor structure, discriminant and convergent validity of TIMSS math and science motivation measures: A comparison of USA and Saudi Arabia. *Journal of Educational Psychology, 105*, 108-128. doi: 10.1037/a0029907

Marsh, H.W., & Ayotte, V. (2003). Do multiple dimensions of self-concept become more differentiated with age? The differential distinctiveness hypothesis. *Journal of Educational Psychology, 95*, 687-706. doi: 10.1037/0022-0663.95.4.687

Marsh, H.W., Byrne, B.M., & Yeung, A.S. (1999). Causal ordering of academic self-concept and achievement: Reanalysis of a pioneering study and revised recommendations. *Educational Psychologist, 34*, 155-167. doi: 10.1207/s15326985ep3403_2

Marsh, H.W., & Craven, R.G. (2006). Reciprocal effects of self-concept and performance from a multidimensional perspective. Beyond seductive pleasure and unidimensional perspectives. *Perspectives on Psychological Science, 1*, 133-163. doi: 10.1111/j.1745-6916.2006.00010.x

Marsh, H.W., Craven, R.G., & Debus, R. (1991). Self-concepts of young children aged 5 to 8: Their measurement and multidimensional structure. *Journal of Educational Psychology, 83*, 377-392. doi: 10.1037/0022-0663.83.3.377

Marsh, H.W., Craven, R.G., & Debus, R. (1998). Structure, stability, and development of young children's self-concepts: A multicohort-multioccasion study. *Child Development, 69,* 1030-1053. doi: 10.1111/j.1467-8624.1998.tb06159.x

Marsh, H.W., Craven, R.G., & Debus, R. (1999). Separation of competency and affect components of multiple dimensions of academic self-concept: A developmental perspective. *Merrill-Palmer Quarterly, 45*, 567-601.

Marsh, H.W., Debus, R., & Bornholt, L.J. (2005). Validating young children's self-concept responses: Methodological ways and means to understand their responses (pp.138-160). In D.M. Teti (Ed.), *Handbook of research methods in developmental science.* Oxford, UK: Blackwell.

Marsh, H.W., Dowson, M., Pietsch, J., & Walker, R. (2004). Why multicollinearity matters: A reexamination of relations between self-efficacy, self-concept, and achievement. *Journal of Educational Psychology, 96*, 518-522. doi: 10.1037/0022-0663.96.3.518

Marsh, H.W., Ellis, L.A., & Craven, R.G. (2002). How do preschool children feel about themselves: Unravelling measurement and multidimensional self-concept structure. *Developmental Psychology, 38*, 376-393. doi: 10.1037/0012-1649.38.3.376

Marsh, H.W., & Hau, K.-T. (1996). Assessing goodness of fit: Is parsimony always desirable? *Journal of Experimental Education, 64*, 364-390. doi: 10.1080/00220973.1996.10806604

Marsh, H.W., Hau, K.-T., & Kong, K.W. (2002). Multilevel causal ordering or academic self-concept and achievement: Influence of language of instruction (English vs. Chinese) for Hong Kong students. *American Educational Research Journal, 39*, 727-763. doi: 10.3102/00028312039003727

Marsh, H.W., Hau, K.-T., & Grayson, D. (2005). Goodness of fit evaluation in structural equation modeling. In A. Maydeu-Olivares & J. McArdle (Eds.), *Contemporary* *psychometrics. A Festschrift for Roderick P. McDonald* (pp. 275-340). Mahwah NJ: Erlbaum.

Marsh, H.W., Hau, K.-T., & Wen, Z. (2004). In search of golden rules: Comment on hypothesis-testing approaches to cutoff values for fit indexes and dangers in overgeneralizing Hu & Bentler's (1999). *Structural Equation Modeling, 11,* 320-341. doi: 10.1207/s15328007sem1103_2

Marsh, H.W., & Köller, O. (2004). Unification of theoretical models of academic self-concept/achievement relations: Reunification of east and West German school systems after the fall of the Berlin Wall. *Contemporary Educational Psychology, 29*, 264-282. doi:10.1016/S0361-476X(03)00034-1

Marsh, H.W., & Martin, A.J. (2011). Academic self-concept and academic achievement: Relations and causal ordering. *British Journal of Educational Psychology, 81*, 59-77. doi: 10.1348/000709910X503501

Marsh, H.W., & O'Mara, A.J. (2008). Self-concept is as multidisciplinary as it is multidimensional. In H.W. Marsh, R.G. Craven, & D.M. McInerney (Eds.), *Self-processes, learning, and enabling human potential. Dynamic new approaches* (pp. 87-115). Charlotte, NC: Information Age.

Marsh, H.W., Trautwein, U., Lüdtke, O., Köller, O., & Baumert, J. (2005). Academic self-concept, interest, grades and standardized test scores: Reciprocal effects model of causal ordering. *Child Development, 76*, 397-416. doi: 10.1111/j.1467-8624.2005.00853.x

Marsh, H.W., & Yeung, A.S. (1998). Longitudinal structural equation models of academic self-concept and achievement: Gender differences in the development of math and English constructs. *American Educational Research Journal, 35*, 705-738. doi: 10.3102/00028312035004705

McClelland, M.M., Cameron, C.E., McDonald Connor, C., Farris, C.L., Jewkes, A.M., & Morrison, F.J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology, 43*, 947-959. doi: 10.1037/0012-1649.43.4.947

Meredith, W. (1993). Measurement invariance, factor analysis and factorial invariance. *Psychometrika, 58*, 525-543. doi: 10.1007/BF02294825

Möller, J., Pohlmann, B., Köller, O., & Marsh, H.W. (2009). Meta-analytic path analysis of the internal/external frame of reference model of academic achievement and academic self-concept. *Review of Educational Research, 79*, 1129-1167. doi: 10.3102/0034654309337522

Möller, J., Retelsdorf, J., Köller, O., & Marsh, H.W. (2011). The reciprocal internal/external frame of reference model: An integration of models of relations between academic achievement and self-concept. *American Educational Research Journal, 48*, 1315-1346. doi: 10.3102/0002831211419649

Möller, J., Zimmermann, F., & Köller, O. (2014). The reciprocal internal/external frame of reference model using grades and test scores. *British Journal of Educational Psychology, 84,* 591-611. doi: 10.1111/bjep.12047

Muijs, R.D. (1997). Predictors of academic achievement and academic self-concept: A longitudinal perspective. *British Journal of Educational Psychology, 67*, 263-277. doi: 10.1111/j.2044-8279.1997.tb01243.x

Muthén, L.K., & Muthén, B.O. (1998–2012). *Mplus user's guide. Seventh edition*. Los Angeles, CA: Muthén & Muthén.

Nagengast, B., Marsh, H.W., Scalas, L.F., Xu, M., Hau, K.-T, & Trautwein, U. (2011). Who took the "x" out of expectancy-value theory? A psychological mystery, a substantive-methodological synergy, and a cross-national generalization. *Psychological Science, 22,* 1058-1066. doi: 10.1177/0956797611415540

Nicholls, J.G. (1979). Development of perception of own attainment and causal attributions for success and failure in reading. *Journal of Educational Psychology, 71*, 94-99. doi: 10.1037/0022-0663.71.1.94

Niepel, C., Brunner, M., & Preckel, F. (2014). The longitudinal interplay of students' academic self-concepts and achievements within and across domains: Replicating and extending the reciprocal internal/external frame of reference model. *Journal of Educational Psychology, 106*, 1170-1191.doi: 10.1037/a0036307

Obach, M.S. (2003). A longitudinal-sequential study of perceived academic competence and motivational beliefs for learning among children in middle school. *Educational Psychology, 23,* 323-338. doi: 10.1080/0144341032000060156

O'Mara, A.J., Marsh, H.W., Craven, R.G., & Debus, R.L. (2006). Do self-concept interventions make a difference? A synergistic blend of construct validation and meta-analysis. *Educational Psychologist, 41*, 181-206. doi: 10.1207/s15326985ep4103_4

Parker, P.D., Marsh, H.W., Ciarrochi, J., Marshall, S., & Abduljabbar, A.S. (2014). Juxtaposing math self-efficacy and self-concept as predictors of long-term achievement outcomes. *Educational Psychology, 34*, 29-48. doi: 10.1080/01443410.2013.797339

Pinxten, M., Marsh, H.W., De Fraine, B., Van Den Noortgate, W., & Van Damme, J. (2014). Enjoying mathematics or feeling competent in mathematics? Reciprocal effects on mathematics achievement and perceived math effort expenditure. *British Journal of Educational Psychology, 84*, 152-174. doi: 10.1111/bjep.12028

Preßler, A.-L., Krajewski, K., & Hasselhorn, M. (2013). Working memory capacity in preschool children contributes to the acquisition of school relevant precursor skills. *Learning and Individual Differences, 23*, 138-144. doi:10.1016/j.lindif.2012.10.005

Ruble, D., Boggiano, A.K., Feldman, N.S., & Loebl, J.H. (1980). Developmental analyses of the role of social comparison in self-evaluation. *Developmental Psychology, 16*, 105-115. doi: 10.1037/0012-1649.16.2.105

Raykov, T. (2009). Evaluation of scale reliability for unidimensional measures using latent variable modeling. *Measurement and Evaluation in Counseling and Development, 42*, 223-232. doi: 10.1177/0748175609344096

Raines-Eudy, R. (2000). Using structural equation modeling to test for differential reliability and validity: An empirical demonstration. *Structural Equation Modeling: A Multidisciplinary Journal, 7*, 124-141. doi: 10.1207/S15328007SEM0701_07

Shavelson, R.J., Hubner, J.J., & Stanton, G.C. (1976). Self-concept: Validation of construct interpretations. *Review of Educational Research, 46*, 407-441.

Skaalvik, E.M., & Hagtvet, K.A. (1990). Academic achievement and self-concept: An analysis of causal predominance in a developmental perspective. *Journal of Personality and Social Psychology, 58*, 292-307. doi: 10.1037/0022-3514.58.2.292

Skaalvik, S., & Skaalvik, E.M. (2004). Gender differences in math and verbal self-concept, performance expectations, and motivation. *Sex Roles, 50*, 241-252. doi: 10.1023/B:SERS.0000015555.40976.e6

Skaalvik, E.M., & Valas, H. (1999). Relations among achievement, self-concept, and motivation in mathematics and language: A longitudinal study. *Journal of Experimental Education, 67*, 135-149. doi: 10.1080/00220979909598349

Spinath, B., & Spinath, F.M. (2005). Longitudinal analysis of the link between learning motivation and competence beliefs among elementary school children. *Learning and Instruction, 15*, 87-102. doi:10.1016/j.learninstruc.2005.04.008

Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early Childhood Research Quarterly, 19*, 99-120. doi:10.1016/j.ecresq.2004.01.002

Stipek, D.J., & Daniels, D.H. (1988). Declining perceptions of competence: A consequence of changes in the child or in the educational environment? *Journal of Educational Psychology, 80*, 352-356. doi: 10.1037/0022-0663.80.3.352

Stipek, D.J., & MacIver , D.M. (1989). Developmental changes in children's assessment of intellectual competence. *Child Development, 60*, 521-538. doi: 10.2307/1130719

Tiedemann, J., (2000). Parents' gender stereotypes and teachers' beliefs as predictors of children's concept of their mathematical ability in elementary school. *Journal of Educational Psychology, 92*, 144-151.

Trautwein, U., Lüdtke, O., Köller, O., & Baumert, J. (2006). Self-esteem, academic self-concept, and achievement: How the learning environment moderates the dynamics of self-concept. *Journal of Personality and Social Psychology, 90*, 334-349. doi: 10.1037/0022-3514.90.2.334

Trautwein, U., Lüdtke, O., Schnyder, I., & Niggli, A. (2006). Predicting homework effort: Support for a domain-specific, multilevel homework model. *Journal of Educational Psychology, 98*, 438-456. doi: 10.1037/0022-0663.98.2.438

Valentine, J.C., DuBois, D.L., & Cooper, H. (2004). The relation between self-beliefs and academic achievement: A meta-analytic review. *Educational Psychologist, 39*, 111-131. doi: 10.1207/s15326985ep3902_3

Wigfield, A., & Karpathian, M. (1991). Who am I and what can I do? Children's self-concepts and motivation in achievement solutions. *Educational Psychologist, 26*, 223-261. doi:10.1080/00461520.1991.9653134

Wigfield, A., (1994). Expectancy-value theory of achievement motivation: A developmental perspective. *Educational Psychology Review, 6,* 49-78. doi: 10.1007/BF02209024

Wigfield, A., & Eccles, J.S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology, 25,* 68-81. doi:10.1006/ceps.1999.1015

Wigfield, A., Eccles, J.S., Yoon, K.S., Harold, R.D., Arbreton, A.J.A., Freedman-Doan, C., & Blumenfeld, P.C. (1997). Change in children's competence beliefs and subjective task values across the elementary school years: A 3-year study. *Journal of Educational Psychology, 89*, 451-469. doi: 10.1037/0022-0663.89.3.45

Wilgenbusch, T., & Merrell, K.W. (1999). Gender differences in self-concept among children and adolescents: A meta-analysis of multidimensional studies. *School Psychology Quarterly, 14*, 101-120. doi: 10.1037/h0089000

Table 1
Goodness-of-fit Indices

	χ^2	df	CFI	TLI	RMSEA	RMSEA 90% CI	SRMR	Model description
1	173.919	114	.931	.907	.035	[.024; .046]	.049	CFA: Global factors of math self-concept at each measurement point, no separation between competence and affect components
2	125.668	102	.973	.959	.024	[.000; .036]	.044	CFA: Separate factors for the competence and affect components of math self-concept at each measurement point
3	379.864	261	.950	.933	.033	[.025; .040]	.054	CFA: Separate factors for math competence self-concept, math affect self-concept, and early math achievement at each measurement point
4	243.432	157	.953	.937	.036	[.027; .045]	.053	SEM: Cross-lagged panel model for relations between math competence self-concept and early math achievement
5	76.888	64	.991	.986	.022	[.000; .038]	.033	SEM: Cross-lagged panel model for relations between math affect self-concept and early math achievement
6	692.904	522	.932	.908	.039	[.031; .047]	.071	CFA: Invariant factor pattern for the early math achievement and math self-concept (both competence and affect components) factors across gender (configural invariance)
7	719.131	540	.929	.907	.040	[.032; .047]	.079	CFA: Invariant factor loadings for the math achievement and math self-concept (both competence and affect components) factors across gender (weak measurement invariance)
8	740.000	558	.927	.909	.039	[.031; .047]	.082	CFA: Invariant factor loadings and item intercepts for the early math achievement and math self-concept (both competence and affect components) factors across gender (strong measurement invariance)
9	750.956	567	.927	.909	.039	[.031; .047]	.085	CFA: Invariant factor loadings, item intercepts, and factor variances for the early math achievement and math self-concept (both competence and affect components) factors across gender
10	796.598	603	.923	.910	.039	[.031; .046]	.088	CFA: Invariant factor loadings, item intercepts, factor variances, and factor covariances for the early math achievement and math self-concept (both competence and affect components) factors across gender
11	812.959	612	.920	.908	.040	[.032; .047]	.090	CFA: Invariant factor loadings, item intercepts, factor variances, factor covariances, and factor means for the early math achievement and math self-concept (both competence and affect components) factors across gender

Note. All models were estimated by the maximum likelihood estimator with robust standard errors (MLR) and integrated correlated uniquenesses between repeatedly used items.
CFI = comparative fit index; TLI = Tucker-Lewis index: RMSEA = the root mean square error of approximation; CI = confidence interval, SRMR = standardized root mean square residual.

Table 2

Math Self-concept Items with their Standardized Factor Loadings at each Measurement Point (retrieved from Model in Table 1)

	T1	T2	T3
Math Competence Self-concept			
Are you good at telling the time?	.380	.255	.144
Do you know lots of different shapes?	.440	.432	.374
Are you good at counting?	.540	.505	.636
Do you know lots of numbers?	.664	.783	.612
Math Affect Self-concept			
Do you like playing number games?	.586	.475	.564
Do you like saying numbers?	.720	.892	.650

Note. For all $p \leq .001$.

Table 3

Standardized Factor Correlations (Model 3 in Table 1)

	Math Competence T1	Math Affect T1	Math Achievement T1	Math Competence T2	Math Affect T2	Math Achievement T2	Math Competence T3	Math Affect T3
Math Affect T1	.882***							
Math Achievement T1	.402***	.123						
Math Competence T2	.574***	.358***	.424***					
Math Affect T2	.257**	.279**	.129	.715***				
Math Achievement T2	.411***	.144*	.919***	.418***	.075			
Math Competence T3	.278**	.237*	.515***	.499***	.263**	.468***		
Math Affect T3	.345**	.386***	.249**	.360**	.415***	.175*	.677***	
Math Achievement T3	.417***	.263**	.785***	.374***	.147	.846***	.532***	.242*

Note. *** $p < .001$; ** $p < .01$; * $p < .05$.

Table 4

Manifest Means (and Standard Deviations in Parentheses) Separated by Gender

	Math Self-concept						Math Achievement		
	Math Competence T1	Math Competence T2	Math Competence T3	Math Affect T1	Math Affect T2	Math Affect T3	Math Achievement T1	Math Achievement T2	Math Achievement T3
Boys	2.06 (0.70)	2.16 (0.64)	2.25 (0.57)	1.86 (0.99)	1.90 (0.95)	1.92 (0.90)	3.65 (1.54)	4.33 (1.24)	5.18 (0.59)
Girls	2.10 (0.64)	2.04 (0.56)	2.15 (0.51)	2.02 (0.84)	2.02 (0.82)	1.97 (0.80)	3.51 (1.55)	4.07 (1.41)	5.13 (0.61)

Table 5

Standardized Path Coefficients of Models 4 and 5 in Table 1

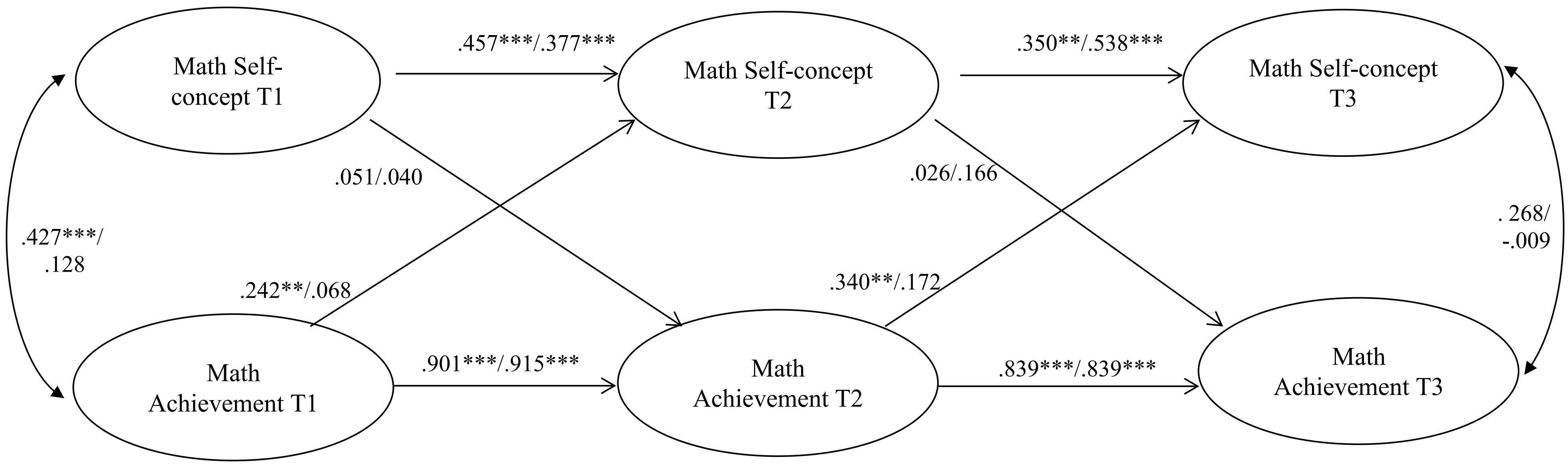
	Model 4	Model 5
Achiev T1 → Achiev T2	.901***	.915***
Achiev T2 → Achiev T3	.839***	.839***
Achiev T1 → Comp T2	.242**	
Achiev T2 → Comp T3	.340**	
Achiev T1 → Affect T2		.068
Achiev T2 → Affect T3		.172
Comp T1 → Comp T2	.457***	
Comp T2 → Comp T3	.350*	
Comp T1 → Achiev T2	.051	
Comp T2 → Achiev T3	.026	
Affect T1 → Affect T2		.377**
Affect T2 → Affect T3		.538***
Affect T1 → Achiev T2		.040
Affect T2 → Achiev T3		.166

Note. Achiev = Early math achievement; Comp = Math competence self-concept; Affect = Math affect self-concept.

*** $p < .001$; ** $p < .01$; * $p < .05$.

Figure 1

Results of the Cross-lagged Panel Models for the Longitudinal Relations between Math Self-concept and Early Math Achievement (Models 4 and 5 in Table 1)



Note. Standardized solution. Coefficients before the slash refer to Model 4(for the competence component of math self-concept); coefficients behind the slash refer to Model 5 (for the affect component of math self-concept).

*** $p < .001$; ** $p < .01$; * $p < .05$.

Highlights:

- Preschoolers separate between competence and affect facets of math self-concept

- Early math achievement relates to math competence self-concept

- Early math achievement is not related to math affect self-concept

- No gender differences in self-concept-achievement relations

- Similar mean levels in math competence and affect self-concepts for boys and girls