Developmental trajectories of school-beginners' ability self-concept, intrinsic value, and performance in mathematics

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Abstract

Background

Although research clearly demonstrates the importance of motivation in mathematics learning, relatively little is known about the developmental dynamics between different facets of mathematics motivation and performance, especially in the early years of schooling.

Aims

In a longitudinal setting, we examined (1) how children's ability self-concept and intrinsic value in mathematics change over time during their first three years in school, (2) how those changes relate to each other, and (3) how they connect with mathematics performance.

Sample

The participants were 285 Finnish school-beginners (52.7 % girls).

Methods

Latent growth curve modelling was used to examine the developmental trajectories of children's ability self-concept and intrinsic value, and how those trajectories predicted later mathematics achievement (both mathematics test performance and teacher-rated grades), while controlling for previous mathematics performance and gender.

Results

The results showed significant decreases in children's ability self-concept and intrinsic value, but also significant individual differences in the trajectories. The strong dependency between the levels and changes in self-concept and intrinsic value led us to specify a factor-of-curves latent growth model, thus merging the trajectories of ability self-concept and intrinsic value into one common model. Subsequent results showed prior mathematics performance to predict change in children's mathematics motivation, and both the level and change in mathematics motivation to predict third-grade performance and teacher-rated grade.

Conclusions

Our findings provide evidence for a developmental link between children's ability self-concept, intrinsic value, and achievement. Achievement seems to enhance mathematics motivation, and positive motivation appears to support the further development of mathematics skills.

Keywords: ability self-concept, intrinsic value, mathematics, development, elementary school

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Introduction

As several countries have witnessed a decline in mathematics performance in recent years (OECD, 2019), the concerns about this trend and the underlying reasons seem rather global, despite the idiosyncrasies of different educational systems. Finland is no exception here. Complementing this trend, representative national studies have further shown key aspects students' mathematics motivation (e.g., perceptions of one's competence and interest) to decrease not only over time, but also across different age cohorts (Metsämuuronen, 2013). To trace the sources of these changes and to consider their implications for teaching, we first need a better understanding of the dynamics between mathematics motivation and performance during the early school years. In the present study, we expand on previous findings on this topic by investigating how children's motivation in mathematics develops over time from the first to the third grade, and how this development is linked with children's mathematics performance. To do this, we draw on the expectancy-value approach to motivation.

Expectancy-Value Framework

The expectancy-value theory (EVT; Wigfield & Eccles, 2000; for recent extensions, see Eccles & Wigfield, 2020) is one of the most prominent approaches to the study of motivation, achievement, and educational choices. It focuses on two components of motivation that are likely predictors of students' commitment, engagement, and performance in academic settings: beliefs about one's ability in a certain domain, and the value ascribed to it. While a belief about one's ability is usually considered as a unidimensional construct, value beliefs can be divided into several facets such as intrinsic value (the enjoyment derived from an activity or interest in a task), attainment value (personal importance of succeeding in a task), and utility value (perceived usefulness of success in a task). Cost, in contrast, describes the perceived negative consequences of engaging in a task (e.g., missing other opportunities). In the long run, these motivational beliefs importantly shape students' choices of educational and career-related pathways (Simpkins et al., 2006; Viljaranta, Nurmi, et al., 2009; Watt, 2006; Watt et al., 2012). The expectancy-value framework has been extensively applied in studies linking mathematics motivation with both achievement and mathematics-related educational and occupational choices (Aunola et al., 2006; Lauermann et al., 2017; Lazarides et al., 2018; Watt et al., 2012), thus making it highly relevant for mathematics education (Schukajlow et al., 2017).

In this study, we use EVT as a theoretical umbrella under which we position related prior research and our own study. That is, although we focus on ability self-concept and intrinsic value as the two key aspects of expectancies and values, we draw more broadly on studies that represent considerable empirical overlap, despite the differences in theoretical nuances and the concepts employed (e.g., competence perceptions, ability judgments, or self-concepts, and intrinsic motivation, interest, or intrinsic value, respectively).

Ability self-concept refers to one's evaluation of current competence or ability in a certain subject area or learning content (Marsh et al., 2019; Wigfield et al., 2016), whereas intrinsic value represents the enjoyment attached to a certain learning content and gained from engaging with it (Eccles & Wigfield, 1995; Gaspard et al., 2020). While the different facets of task values seem to become more clearly differentiated only until the upper elementary school years, the specificity of ability self-concepts and intrinsic values with respect to different school subjects seems evident already among school-beginners (Eccles et al., 1993; Wigfield, 1994).

Mutual Connections and Changes in Self-Concept and Intrinsic Value

Within the EVT, student's self-concepts and intrinsic value in a certain domain are postulated to be positively associated. Numerous cross-sectional studies across various grade-levels and school domains support this notion, and this coupling seems to be particularly strong in mathematics (Bong et al., 2012; Spinath & Steinmayr, 2008; Trautwein et al., 2012). The average development of mathematics self-concept and intrinsic value also seems to follow a similar decreasing trend. Such a decline has been observed already from the early school years onwards, and compared to other school subjects, it seems to be especially pronounced in mathematics (Fredricks & Eccles, 2002; Gaspard et al., 2020; Gottfried et al., 2007; Jacobs et al., 2002; Weidinger et al., 2017). The decline in self-concept may partly reflect natural developmental changes: younger students tend to have overly optimistic beliefs of their competencies, which then become more realistic due to students' cognitive maturation and increased social comparison (Fredricks & Eccles, 2002; Stipek & Iver, 1989). Decline in intrinsic value might, in turn, be due to mathematics becoming more complex and challenging, thus making it less intrinsically appealing (Hidi, 2000). This might also represent a self-protective function: when the learning contents become more difficult, and competition in the classroom context becomes more evident, lowering one's value could help to protect one's self-esteem (Fredricks & Eccles, 2002).

Despite the concurrent dependencies and similar longitudinal changes, the mutual predictions between self-concept and intrinsic value in mathematics seem more complex. Some studies show positive effects from self-concept to intrinsic value or interest (Arens et al., 2019; Marsh et al., 2005; Viljaranta et al., 2014), while others report opposite predictions (Ganley & Lubienski, 2016; Xu, 2018). Yet, in some studies these effects have been mixed, weak, or entirely absent (Pinxten et al., 2014; Spinath & Steinmayr, 2008, 2012). The limited evidence available on the connections between the developmental trajectories of mathematics self-concept and intrinsic value suggests parallel changes over time. For example, Jacobs et al. (2002) found competence beliefs in mathematics to explain a substantial share of the changes in students' task values (interest, importance, and utility), and this effect to be especially pronounced during the early grades (see also Petersen & Hyde, 2017). Studies examining similar connections during specific tasks have also shown changes in expectancy and interest to be strongly correlated (Niemivirta & Tapola, 2007; Nuutila et al., 2021).

Connections of Self-Concept and Intrinsic Value with Achievement

In addition to their mutual relations, self-concept and intrinsic value also tend to go hand in hand with achievement. That is, students seem more likely to believe in their abilities and enjoy academic activities, if they at the same time succeed well in them (Denissen et al., 2007). This also is in line with the EVT, which argues that students' expectancies, values, and achievement develop in mutually reinforcing cycles (Wigfield & Eccles, 2000). Accordingly, research has shown students' previous achievement to predict both competence beliefs (e.g., Arens et al., 2019; Helmke & van Aken, 1995; Viljaranta et al., 2014) and intrinsic motivation in mathematics (e.g., Garon-Carrier et al., 2016; Viljaranta, Lerkkanen, et al., 2009), which, in turn, contribute to students' subsequent achievement. Intrinsic motivation has shown to predict mathematics achievement already during the first school years (Aunola et al., 2006; Gottfried, 1990), or even in preschool (Viljaranta, Lerkkanen, et al., 2009). Similarly, competence beliefs have been found to predict mathematics achievement relatively early on (Weidinger et al., 2018). Generally, however, the reciprocal relations with achievement seem more systematic and stronger for competence beliefs than for intrinsic value (Schneider et al., 2018; Weidinger et al., 2017; Xu, 2018).

Less is again known about how the developmental trajectories of self-concept and intrinsic value connect with achievement. Whether previous achievement predicts motivational trajectories seems to partially depend on the subject domain and the methodology employed. Regarding mathematics, some studies have shown prior achievement or aptitude to be linked with changes in mathematics-related expectancies and intrinsic motivation (Benden & Lauermann, 2021; Gaspard et al., 2020; Gottfried et al., 2007), while some have failed to do so (Musu-Gillette et al., 2015). The predictions of trajectories of self-concept and intrinsic value on achievement and other academic outcomes such as course enrolment and career choices, instead, point out to the added value of positive (or less negative) motivational change over time (Ahmed et al., 2013; Gaspard et al., 2020; Gottfried et al., 2013; Musu-Gillette et al., 2015). Note, however, that the study designs and approaches to modelling change in these studies vary considerably, thus complicating the conclusions. For example, Gaspard et al. (2020) argued based on their analyses on different trajectory classes (i.e., groups of students with qualitatively different patterns of changes in ability self-concepts and intrinsic values) that besides the extent of motivational change in a subject domain, the effects on outcomes depend on the intraindividual hierarchies (i.e., relative levels) of ability self-concepts and intrinsic values across different domains. That is, the predictions of motivational changes in one domain may depend on the motivational changes in another domain.

Unfortunately, none of the above studies have looked at the developmental dynamics during the very first years of education. Design-wise closest to the present one is the study by Petersen and Hyde (2017), who investigated the developmental trajectories of mathematics-related ability self-concept, utility value, and interest in 5th, 7th, and 9th grades. Partly concurring with previous research, they found mathematics interest and utility value to decrease over time, while no change was observed in ability self-concept. Changes in self-concept and values correlated with each other, and changes in mathematics self-concept predicted mathematics performance five years later, even when controlling for prior performance. Neither interest nor utility value trajectories contributed to later performance.

Present Study

Grounding on prior research we addressed some of the open issues through following research questions: (1) how do school-beginners' ability self-concept and intrinsic value in mathematics change from first to third grade, (2) how are changes in ability self-concept and intrinsic value related to each other, and (3) how do those changes predict later mathematics performance and achievement?

Based on previous studies, we expected both ability self-concept and intrinsic value to decline over time (Fredricks & Eccles, 2002; Gaspard et al., 2020; Gottfried et al., 2001, 2007; Jacobs et al., 2002; Weidinger et al., 2017), and those changes to be correlated (Petersen & Hyde, 2017). We also anticipated ability self-concept and intrinsic value to be related to mathematics performance, in terms of both the level (i.e., more positive self-concept and higher intrinsic value to be correlated with better performance) and change (i.e., more positive change in self-concept and intrinsic value to predict better later performance) (Denissen et al., 2007; Petersen & Hyde, 2017; Schneider et al., 2018; Weidinger et al., 2018).

Since previous research has identified some relatively consistent gender differences in mathematics motivation (Ganley & Lubienski, 2016; Jacobs et al., 2002), we also took this into account by including gender as a covariate. Although boys have shown to display stronger confidence in their mathematical abilities (Fredricks & Eccles, 2002; Herbert & Stipek, 2005) and higher intrinsic value (Frenzel et al., 2010; Lee & Kim, 2014) than girls during the adolescent years, we did not expect such differences in the first grade (Viljaranta, Lerkkanen, et al., 2009). However, we did anticipate the possible change in self-concept favouring boys to become observable over time.

Method

Participants and Procedure

The participants were Finnish students (*N* = 285; 52.7 % girls) from 17 classes in seven schools in the metropolitan area in Finland. All participating schools were in middle-class, largely ethnically Finnish areas. A researcher visited the schools each spring during the first, second, and third grades to collect the data in group sessions during regular classes. In each session, the researcher first explained the children the procedure making sure the children understood the tasks and how to respond. The children then completed their sheets. Participation was voluntary, written consent was given by parents, and confidentiality was assured.

Measures

Mathematics Ability Self-Concept and Intrinsic Value

As the participants were first-graders (around seven years of age) in the beginning of the study, we could not expect them to read fluently. Therefore, all items were shown on a screen and read aloud. For responses, four smiley faces gradually changing from a sad to a happy face to represent the degree of agreement with the statement were used (see Appendix). The meaning and use of the scale was explained to the children with examples. Also, to keep the task as clear and straightforward as possible, we used simple indicators of our target constructs, derived from measures used in previous EVT studies (e.g., Eccles et al., 1993; Jacobs et al., 2002). Mathematics self-concept was measured with the question *How good you think you are in mathematics?*, whereas intrinsic value in mathematics was measured with two items representing two key aspects of intrinsic value, liking, *How much do you like mathematics?,* and enjoyment, *How much do you enjoy being in math classes?.* For the data analyses, children's responses to the four smiley faces from sad to happy were then coded with corresponding values ranging from 1 to 4. Cronbach's alphas for the mean scores of the two intrinsic value items were .83, .87, and .88 for t1, t2, and t3, respectively.

Mathematics Performance

To assess children's basic mathematics skills, we used nationally normed age-appropriate mathematics tests LukiMat (Koponen et al., 2011) at the first grade (M = 17.70, SD = 3.89), and RMAT (Räsänen, 2004) at the third grade (M = 26.60, SD = 4.38). As the RMAT is relatively narrow in scope focusing on basic mathematical operations, we also included teacher ratings at the third grade to obtain a more comprehensive assessment of children's mathematics competence. As the children in Finland are not formally graded and no national mathematics tests are used during the first school years, we had the teachers grade each child using the grading scale from 4 (fail) to 10 (excellent) normally applied in Finnish schools in later years ($M = 8.56$, $SD = 0.96$).

Analyses

Latent growth curve modelling (LGCM) within the structural equation modelling framework was used for all analyses (Duncan et al., 1999). In LGCM, repeated measurements of observed variables are used as manifest indicators for the estimation of latent variables representing the two components of a change, initial level (onset of change) and slope (rate of change). The modelling proceeded in four steps: (1) an estimation of univariate LGC models describing change in ability self-concept and intrinsic value separately; (2) an estimation of a parallel process model examining connections between the changes in ability self-concept and intrinsic value; (3) an estimation of a prediction model with gender and first grade mathematics performance as covariates; and (4) an estimation of a full model with third grade mathematics performance and teacher-rated grades as dependent variables. The full model is illustrated in Figure 1.

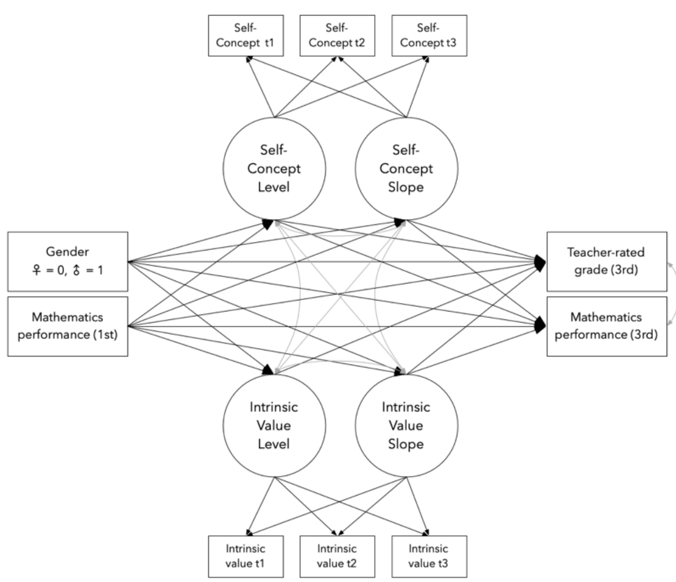

Figure 1. *The hypothetical full model tested through a series of latent growth curve models.*

To evaluate model fit, we used multiple indices in line with the recommendations by Kline (2016): the Comparative Fit Index (CFI; Bentler, 1990), Root Mean Square Error of Approximation (RMSEA; Steiger, 1990), and Standardized Root Mean Square Residual (SRMR; Hu & Bentler, 1999) along with the chi-square statistics. For all analyses, maximum likelihood estimation with robust standard errors (MLR) was used, and missing data (Little's MCAR test: $\chi^2(257) = 244.949$, $p = .695$) were handled with full-information maximum likelihood method, as implemented in the M*plus* 8.6 statistics program (Muthén & Muthén, 1998–2017).

Results

Measurement Invariance and Descriptive Statistics

To ensure first that our measures of mathematics self-concept and intrinsic value were equivalent over time, we tested for longitudinal measurement invariance, even with the limited number of parameters to be estimated. To do this, we ran a series of two-factor models with increasing restrictions on the parameters (see, Widaman et al., 2010) thus evaluating four levels of invariance: configural (same factor pattern), weak (invariant factors loadings), strong (invariant factor loadings and item intercepts), and strict (invariant factor loadings, item intercepts, and item variances), respectively. As the change in model fit between all four models did not show significant deterioration (Table 1), and the fit of the most restricted model was excellent, $\chi^2(18) = 20.08$, $p = .328$, CFI = .997, RMSEA = .020, SRMR = .031, thus supporting measurement invariance over time, we calculated means scores for further analyses.

Table 1. *Model fit for tests of measurement invariance.*

Model	χ^2	*df*	*p*	CFI	RSMEA	SRMR	Model comparison	$\Delta\chi^2$	*df*	*p*	ΔCFI	ΔRMSEA	ΔSRMR
M1 Configural	14.76	9	.098	.993	.047	.017							
M2 Weak	15.69	11	.153	.994	.039	.021	M2-M1	1.07	2	.587	.001	–.017	.004
M3 Strong	19.78	14	.137	.993	.038	.026	M3-M2	4.06	3	.255	–.001	–.001	.005
M4 Strict	20.08	18	.328	.997	.020	.031	M4-M3	1.91	4	.752	.004	–.018	.005

As shown in Table 2, the means of mathematics ability self-concept and intrinsic value declined over time, although the overall level was and remained high. Both demonstrated also moderate stability over time, with correlations between measurement points ranging from .33 to .51. Also mathematics performance showed intraindividual stability over time with a correlation of .47 between the first and third grade mathematics test scores. Teacher-rated grades at grade three was strongly linked with third grade mathematics performance.

Table 2. *Descriptive statistics and bivariate correlations.*

	M	*SD*	Self-concept t1	Self-concept t2	Self-concept t3	Intrinsic value t1	Intrinsic value t2	Intrinsic value t3	Mathematics test t1	Mathematics test t3	Teacher grades t3
Self-concept t1	3.60	0.58	—								
Self-concept t2	3.37	0.64	.38***	—							
Self-concept t3	3.30	0.60	.36***	.51***	—						
Intrinsic value t1	3.49	0.67	.55***	.33***	.24***	—					
Intrinsic value t2	3.25	0.75	.37***	.59***	.40***	.50***	—				
Intrinsic value t3	3.08	0.72	.23***	.30***	.48***	.34***	.58***	—			
Mathematics test t1	17.70	3.89	.06	.12*	.32***	.05	.09	.08	—		
Mathematics test t3	26.60	5.83	.17**	.18**	.41***	.13*	.16**	.26***	.47***	—	
Teacher grades t3	8.56	0.96	.16**	.17**	.40***	.16**	.14*	.18**	.53***	.71***	—
Gender			.09	.18**	.21***	.02	.20***	.13*	–.06	.11	.01

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

Changes in Ability Self-Concept and Intrinsic Value

To address our first research question on changes in ability self-concept and intrinsic value, we estimated two separate growth models. The linear LGC model for ability self-concept resulted in an acceptable fit, $\chi^2(1) = 6.01$, $p = .014$; CFI = .934; RMSEA = .133 (90% CI: .047–.243); SRMR = .029. The RMSEA was relatively high but given that this is often expected in simple models with small degrees of freedom (Kenny et al., 2015; Shi et al., 2021), and since the other fit indices were acceptable, we proceeded with this model. The negative estimate for slope was significant ($M = -.147$, $p < .001$), as were the variances of both the initial level ($S^2 = .157$, $p = .001$) and slope ($S^2 = .045$, $p = .017$), thus demonstrating an overall decline in mathematics self-concept and significant individual differences in both the onset and change over time.

The fit for the linear model for intrinsic value was excellent, $\chi^2(1) = 0.938$, $p = .338$; CFI = 1.000; RMSEA = .000 (90% CI: .000–.155); SRMR = .012. Again, the negative slope was significant

(M = –.206, $p < .001$) as were the variances of both the initial level (S^2 = .332, $p < .001$) and slope (S^2 = .116, $p < .001$). Like ability self-concept, then, students' mathematics intrinsic value showed overall decline yet significant individual differences in the trajectories over time (see Figure 2).

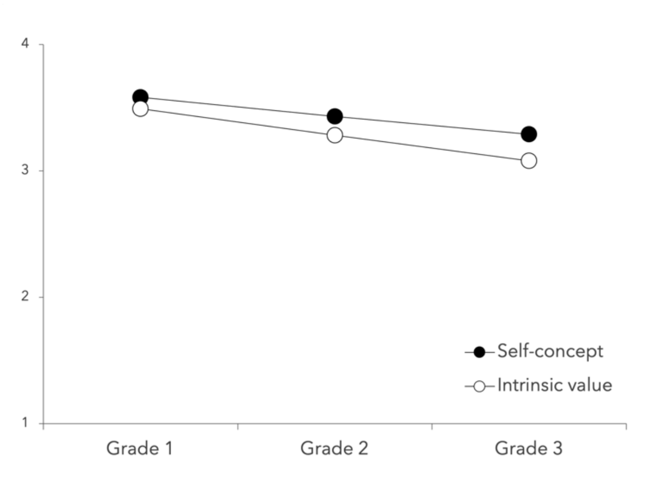

Figure 2. *Model estimated means of the developmental trajectories of mathematics ability self-concept and intrinsic value.*

Connections Between the Changes in Ability Self-Concept and Intrinsic Value

Next, to address our second research question on the connections between changes in ability self-concept and intrinsic value, we estimated a parallel process model where the initial levels and slopes of ability self-concept and intrinsic value were let to correlate. The fit for this multivariate model was not acceptable, $\chi^2(7) = 47.21$, $p < .001$; CFI = .878; RMSEA = .142 (90% CI: .105–.182); SRMR = .084. An inspection of the modification indices suggested a significant covariance between time 2 measures of self-concept and intrinsic value. Since this likely reflected some meaningful additional dependence between students' self-evaluations during the second measurement point, we added the given covariance to the model. As the resulting model fit the data very well, $\chi^2(6) = 5.620$, $p = .467$; CFI = 1.000; RMSEA = .000 (90% CI: .000–.074); SRMR = .024, and the estimates of change remained virtually identical to those in the previous stage, we decided to proceed with this model. The results (see Table 3) showed strong correlations between both the initial levels ($r = .90$, $p < .001$) and slopes ($r = .79$, $p < .001$) of self-concept and intrinsic value, meaning that not only were students' mathematics ability self-concept and intrinsic value highly connected already in the first grade, but also the changes in them over time; less negative change in one was linked with less negative change in the other.

Table 3. *Descriptive statistics and latent correlations from the multivariate latent growth model.*

	M	*s.e.*	*p*	Self-concept Initial level	Self-concept Slope	Intrinsic value Initial level	Intrinsic value Slope
Self-concept Initial level	3.58	0.03	< .001	1.00			
Self-concept Slope	–0.15	0.02	< .001	-0.25	1.00		
Intrinsic value Initial level	3.49	0.04	< .001	0.90**	-0.45**	1.00	
Intrinsic value Slope	–0.21	0.02	< .001	-0.44**	0.79**	-0.44**	1.00

Note. ** p < .001

Predictions of Changes in Ability Self-Concept and Intrinsic Value

In the next steps, we addressed our third research question on the connections between mathematics performance and changes in ability self-concept and intrinsic value by adding predictors and outcomes into the parallel process model. However, the prediction models failed to converge, which might have been due to the high dependencies between the parameters of change in self-concept and intrinsic value. Since this might also be an indication of a higher-order construct underlying the said dependencies, we tested whether a second-order model, a factor-of-curves (FOCUS) model (McArdle, 1988), would capture the trajectories and their joint variation more appropriately (Figure 3).

In the FOCUS model, we used latent growth factors of ability self-concept and intrinsic value to estimate latent factors representing a common onset and slope, as illustrated in Figure 3 (see, Wickrama et al., 2016). Reflecting the presumed underlying common construct, we refer to this second-order trajectory more generally as "mathematics motivation". The base model fit the data well, $\chi^2(10) = 12.079$, $p = .280$; CFI = .994; RMSEA = .027 (90% CI: .000–.073); SRMR = .049, and showed a significant overall decrease in mathematics motivation ($M = –.200$, $p < .001$), as expected. Variances of both initial level (S^2 = .191, p < .001) and change over time (S^2 = .071, p < .001) were also significant.

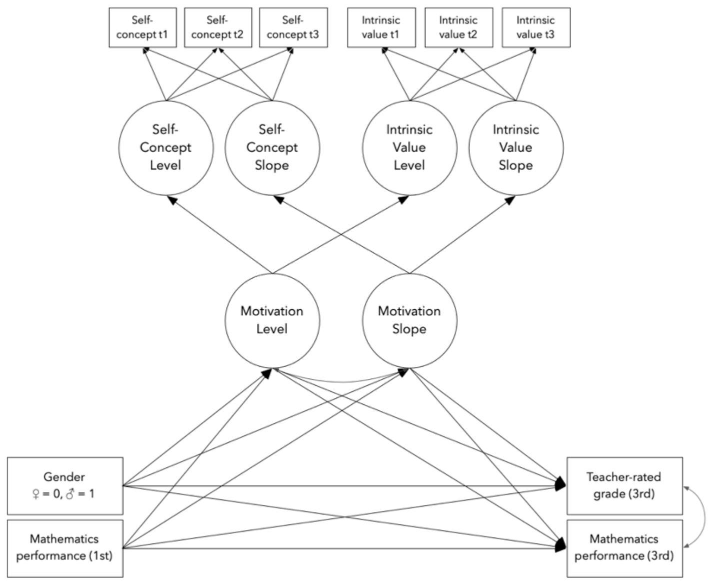

Figure 3. *The factor-of-curves model of mathematics motivation with predictors and outcomes.*

Next, we added gender and first grade mathematics test performance as predictors of change in mathematics motivation. The fit of the model was good, $\chi^2(18)$ = 34.841, p = .010; CFI = .962; RMSEA = .057 (90% CI: .027–.086); SRMR = .054, and the results showed the slope of mathematics motivation to be predicted by both gender (β = .35, p = .013) and prior mathematics performance (β = .23, p = .004). The positive effect of gender indicated that the negative change in mathematics motivation was less steep for boys.

Predictions of Mathematics Performance

In the final step, we included third grade mathematics test performance and teacher-rated grades as outcomes. This full model fit the data well, $\chi^2(26)$ = 42.320, p = .023; CFI = .975; RMSEA = .047 (90% CI: .018–.072); SRMR = .049, and showed the test performance and grades to be predicted by both the initial level of mathematics motivation (β_P = .34, p < .001 and β_G = .32, p = .001) and the change in it (β_P = .36, p < .001 and β_G = .29, p = .001). That is, higher initial mathematics motivation and less steep decrease in it over time were both associated with higher mathematics performance and achievement in the third grade. This was true even when controlling for the significant effect of first grade mathematics performance on third grade mathematics performance ($\beta = .36$, $p < .001$) and teacher-rated grades ($\beta = .43$, $p < .001$). The model explained 34 % and 36 % of the variance in third grade test performance and teacher-rated grades, respectively. Significant main effects are illustrated in Figure 4, and all effects reported in Table 4.

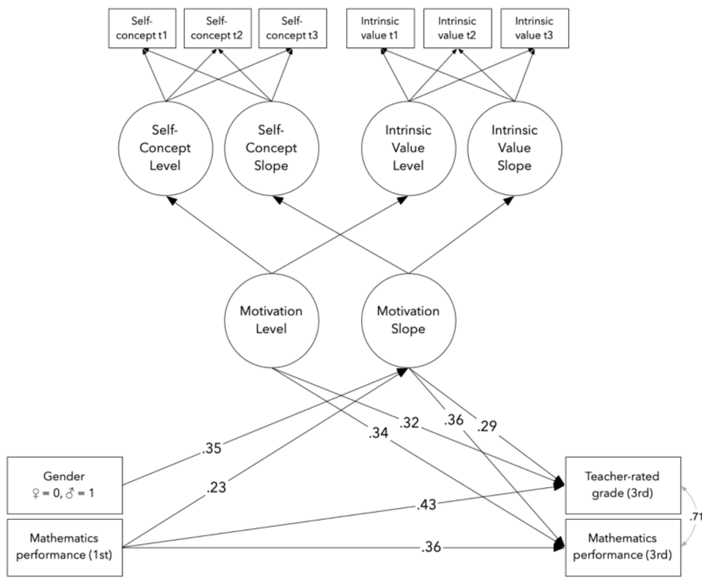

Figure 4. *Significant standardised effects from the factor-of-curves model of mathematics motivation with predictors and outcomes.*

Table 4. *Standardised effects from the full factor-of-curves prediction model.*

	Motivation: level			Motivation: slope			Mathematics test 3rd			Teacher grades 3rd		
Predictor	*β*	*Z*	*p*	*β*	*Z*	*p*	*β*	*Z*	*p*	*β*	*Z*	*p*
Gender	.22	1.54	.125	.35	2.49	.013	.09	0.89	.374	–.08	–0.78	.434
Mathematics test 1st	.10	1.31	.191	.23	2.91	.004	.36	3.59	<.001	.43	3.78	<.001
Motivation: level							.34	4.05	<.001	.32	3.74	<.001
Motivation: slope							.36	3.23	.001	.29	3.26	.001

Discussion

This study investigated the developmental interdependence of mathematics ability self-concept and intrinsic value, and their associations with performance during the first three years of elementary school.

Changes in Ability Self-Concept and Intrinsic Value

As to our first research question, students' ability self-concept and intrinsic value both declined over time from the initial high level onwards, which concurs with our assumptions and previous studies on similar age groups (Fredricks & Eccles, 2002; Gaspard et al., 2020; Gottfried et al., 2001, 2007; Jacobs et al., 2002; Weidinger et al., 2017). Given the age group, the rank-order stability was relatively high, thus also agreeing with prior research (Spinath & Steinmayr, 2008; Viljaranta et al., 2014; Weidinger et al., 2018). Importantly, however, significant individual differences both at the onset and subsequent development of students' mathematics motivation were present, meaning that despite the average decline over time, individual trajectories varied. This also has been documented in other studies (Fredricks & Eccles, 2002; Gottfried et al., 2007; Weidinger et al., 2017), thus reiterating the fact that children may take different developmental paths in their mathematics motivation right from the beginning of formal education.

The observed decline in students' mathematics motivation has mostly been attributed to the developmental changes in children's self-evaluations, the nature of mathematics as a school subject, and changes in the school context (Wigfield & Cambria, 2010). While the correspondence between perceived and actual attainment is still partly inaccurate (mostly overoptimistic) among the school-beginners, growing cognitive capacity and increasingly heightened sensitivity to social comparisons begins to gradually calibrate competence perceptions (Wigfield & Eccles, 2000). The increasing focus on performance and assessment over the elementary school years may further underscore this (Boaler, 2016).

Connections Between the Development of Ability Self-Concept and Intrinsic Value

Regarding the second research question, we found both the initial levels and developmental slopes of ability self-concept and intrinsic value to be strongly correlated. Even to the point that we needed to apply a different modelling approach to the data when including predictors and outcomes. Although this strong dependency may have been partly due to the way ability self-concept and intrinsic value were assessed, it is nevertheless clear that these two aspects of motivation are highly connected, thus supporting our expectations. That is, a more positive view of one's mathematics abilities is linked with how enjoyable the subject is considered, and vice versa, both concurrently and longitudinally. The present data and analyses do not permit any inferences about the causal predominance between ability self-concept and intrinsic value, but most likely their developmental interplay follows a cyclical process, as previously suggested (Marsh et al., 2005; Wigfield & Eccles, 2000). Future research should pay particular attention to the assessment of school-beginners' motivation to have a better view on whether and how the different facets of children's mathematics motivation become differentiated. Perhaps also linking this sort of developmental data with repeated situated measures of daily experiences in the classroom would provide some new insights into how these two facets of motivation contribute to each other.

Predictions of Change in Ability Self-Concept and Intrinsic Value, and Mathematics Performance

Regarding the outcomes, our third question addressed the connections of mathematics performance with changes in mathematics motivation. As mentioned, we had to change our modelling procedure to accommodate the high statistical dependency between the growth parameters of ability self-concept and intrinsic value. Consequently, the applied FOCUS model merged the trajectories of ability self-concept and intrinsic value into higher-order factors representing more general mathematics motivation and change in it. Although this solution loses the differentiated nuances of two qualitatively different aspects of mathematics motivation, it also broadens the scope of our empirical representation of the underlying construct. The findings from this model showed changes in mathematics motivation to be predicted by previous mathematics performance, and to be predictive of later mathematics performance. That is, higher initial mathematics skills were associated with less steep decline in mathematics motivation, which, in turn, was linked with higher subsequent mathematics skills (test performance) and achievement (teacher ratings), even after controlling for the initial mathematics performance. This was in line with our assumptions and concurs with prior studies showing a connection between mathematics motivation and performance (Denissen et al., 2007; Petersen & Hyde, 2017; Schneider et al., 2018; Weidinger et al., 2018), although fails to make a clear distinction in this regard between ability self-concept and intrinsic value. This is unfortunate, given the different role these two aspects of motivation seem to have in students' educational careers in later years. Even so, it is important to note that from a developmental point of view, the change in students' mathematics motivation already at this age is clearly not independent of their mathematics performance, and more importantly, that positive development in motivation (even in the form of less steep decline over time) influences later performance, above and beyond the effect of previous performance. This supports the view that skills and motivation in mathematics develop in a cyclical manner (Marsh et al., 2005), and that this process begins rather early on (Gottfried et al., 2007). This is particularly notable given the fact that school-beginners' views on the subject and their motivational beliefs attached to it are yet only emerging.

Finally, a note on gender differences, even though this was not an actual focus of the study (note, that due to the relevance of gender differences in this context, additional analyses and discussion can be found in Supplementary material). In line with our expectations and previous studies, no gender differences in mathematics performance were found (Tuominen et al., 2021; Viljaranta, Lerkkanen, et al., 2009). However, regarding motivation, we found boys to report less negative development over time. Thus, although gendered motivational processes are not salient at the beginning of children's educational careers, they do seem to emerge soon after.

Limitations, and Suggestions for Future Research

Although our research has the merit of being one of the few to look at the early development of young students' mathematics motivation, and how this relates to mathematics performance, the study is not without limitations. Due to the age and skill level of the participating children at the beginning of the project, we relied on the simplest and most straightforward measures of mathematics self-concept and intrinsic value. Although such an approach may increase consistency, it also simplifies the psychometric quality of the measures. The results themselves lend support for sufficient validity, but broader measures would be preferable to provide a more comprehensive view of the constructs involved. Although young children's mathematics self-concept and intrinsic value are undoubtedly strongly correlated, this dependence may have been inflated by to the measures and assessment practice. This in turn may have contributed to the inability of our model to disentangle the effects of the trajectories of self-concept and intrinsic value when covariates and outcomes were included. This is an important issue to consider in future studies.

Partly for the same reasons, also our measures of mathematics performance were rather narrow in scope. In Finland, children are not graded until grade four, and there are no standardised tests until the matriculation examination after grade 12, so we relied on available measures to assess school beginners' mathematics skills. To broaden the view on children's' mathematics performance, we also included teacher-rated grades in grade three. Even so, a more comprehensive view of children's mathematics competence would be beneficial.

Due to practical realities, our sample was sub-optimal, especially given our focus on the developmental dynamics between multiple constructs, thus limiting statistical power. The challenge of conducting research among school beginners and getting schools and teachers to commit to it is not uncommon, as was the case here. We hope that despite these limitations, our findings nevertheless provide a good starting point for similar research focusing on the developmental interplay between children's mathematics motivation and skill development.

Future research should pay particular attention to the assessment of motivation in the early years of schooling, to gain a better understanding of whether and how the different facets of children's mathematics motivation become differentiated. Perhaps linking this type of developmental data with repeated situated measures of daily classroom experiences would also provide some new insights into how these two facets of motivation contribute to each other. A more comprehensive view of these developments would require extensive longitudinal research, perhaps starting before formal education and continuing through upper secondary education and even beyond. It would not be sufficient to focus only on students' achievements and motivations, but also to trace their classroom experiences, as well as contextual and cultural factors such as instructional strategies and pedagogical processes, and gender stereotypes - not only of teachers and students, but also of parents.

Practical Implications

Due to the growing complexity and cumulative nature of mathematical competence, the maintenance of positive motivational beliefs almost necessitates a solid foundation of basic skills; lacking such foundation may increase doubt in one's abilities, experiences of negative emotions, and diminishing interest (e.g., Pekrun et al., 2017). The decline in motivational beliefs, then, likely reflects not only changes in the educational ethos and age-related calibration processes, but also the growing individual differences in students' mathematical skills and achievements. Consequently, the practical implications for supporting motivation should target both ensuring solid basics skills and implementing everyday classroom activities that diminish social comparison, provide accurate and constructive feedback, and support mastery experiences for all students irrespective of their skill level (e.g., Jansen et al., 2013; Stipek, 2002).

Conclusion

Taken together, our findings evidence the developmental coupling of students' ability self-concept, intrinsic value, and achievement. Achievement seems to enhance mathematics motivation, and positive motivation appears to support the further development of mathematics skills. This implies that an effective classroom instruction should not only focus on building the foundation of mathematics skills, but also make studying mathematics meaningful and intrinsically rewarding, and support students' confidence while they try to keep up with the challenging subject. Given the significant developmental variation among these young students, particular attention should be paid on those who may be drifting into a negative motivational path already from early on.

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APPENDIX

How much do you like mathematics?

How good you think you are in mathematics?

How much do you enjoy being in math classes?