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Relations between mathematics achievement and motivation in students of diverse achievement levels

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ABSTRACT

Due to the diverse achievement experiences of students with diverse achievement levels in heterogeneous primary school classrooms, the relations between motivation and achievement may develop differentially depending upon achievement level. This study investigated the relations between several core aspects of motivation for mathematics – self-efficacy, self-concept, task value, and mathematics anxiety – and achievement with particular attention for potential differences between students of diverse achievement levels. Participants ($N = 4306$ students of grade 2–6) completed a standardised mathematics achievement test at T1 and T3 and a mathematics motivation questionnaire at T2. T1 achievement positively predicted perceived competence (self-efficacy and self-concept combined) and task value and negatively predicted mathematics anxiety. Only perceived competence had a significant effect on T3 achievement after controlling for T1 achievement and working memory, and partially mediated the relation between previous and subsequent achievement. This pattern of effects was largely similar across the full range of achievement levels, although the effect of previous achievement on perceived competence was stronger within the subsample of average-achieving students. These findings highlight the unique contribution of perceived competence in predicting subsequent achievement across students of diverse achievement levels in primary school.

1. Introduction

Motivation and achievement are closely related: students tend to feel more competent in the school subjects in which they achieve well and value these subjects more highly too (Denissen, Zarrett, & Eccles, 2007). On the one hand, prior achievement has positive effects on students' perceived competence and intrinsic motivation (e.g., Chen, Yeh, Hwang, & Lin, 2013; Fast et al., 2010; Garon-Carrier et al., 2016). On the other hand, students who value a subject more and feel more competent are also more likely to invest effort in that subject and will consequently reach higher achievement (e.g., de Bruin, Kok, Leppink, & Camp, 2014). So, the relations between motivation and achievement are theorised to be reciprocal: motivation is not only influenced by previous achievement but also predicts subsequent achievement (e.g., Marsh & Martin, 2011). Hence, students' early learning successes may start a cascade of success, more motivated effort and more success, while early failures may lead to less motivated effort and fewer successes. Different aspects of motivation, however, seem to affect achievement differently. Motivational aspects related to perceived competence (e.g., Valentine, DuBois, & Cooper, 2004) for example, seem to be more strongly related to subsequent achievement than task value (e.g., Garon-Carrier et al., 2016).

Moreover, the relations between motivation and achievement might differ between students. Since primary school classrooms are diverse in terms of the academic ability and achievement level of the students, students' experiences may also differ substantially: some students may experience failure relatively often whereas other students may mostly experience success. Longitudinal research has shown that initial differences in students' success in mathematics can have long-term consequences for their future motivation and mathematics achievement (Gottfried, Marcoulides, Gottfried, Oliver, & Guerin, 2007). This might be because students with different levels of mathematics success may have quite different experiences shaping their motivation. For example, Hampton and Mason (2003) found that students with learning

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disabilities not only experienced less (previous) accomplishment, but also less positive reinforcement from others, fewer role models, and more anxiety than typically-achieving students. The diversity of learning experiences between students of diverse achievement levels might lead to a differential development of relations between motivation and achievement. For example, it might be that motivation is generally more strongly related to achievement in one group of students (e.g., a positive motivational orientation might make a bigger difference for low-achieving students) or it could be that the relative importance of specific motivational variables differs between achievement groups (e.g., achievement might be more strongly related to task value in high-achieving students but more strongly related to self-efficacy in low-achieving students).

In the current study, we investigated the relations between several core aspects of motivation for mathematics – self-efficacy, self-concept, task value, and mathematics anxiety – and achievement with particular attention for potential differences between students of diverse achievement levels in primary school.

1.1. How previous achievement affects motivation

There is ample evidence that previous scholastic experiences influence multiple aspects of motivation. In line with motivational theories (Bandura, 1997; Marsh & Martin, 2011), previous achievement has been found to affect students perceived competence. That is, students who show higher previous mathematics achievement give a higher self-estimate of their capacity to perform mathematics tasks relative to an absolute performance criterion ('I can…', i.e. self-efficacy; Fast et al., 2010; Jungert, Hesser, & Träff, 2014; Kriegbaum, Jansen, & Spinath, 2015), and give a more positive affective evaluation of their own mathematical capacities relative to a normative standard ('I am good at…', i.e., self-concept; e.g., Chen, et al., 2013; Möller, Zimmermann, & Köller, 2014).

Previous achievement also seems to affect the degree to which the student values the task. Task value refers to intrinsic or interest value (enjoyment gained from engaging in the task), personal or attainment value (perceived importance of the task), and utility value (perceived usefulness of the task) (Wigfield & Cambria, 2010). In this article, we use the term 'task value', but we also refer to studies in which the strongly related constructs of interest and intrinsic motivation for mathematics were investigated using similar measures; see Wigfield and Cambria (2010) for a review of similarities and differences between these constructs. Several longitudinal[1] studies have reported small to moderate positive effects of previous mathematics achievement on subsequent task value (Garon-Carrier et al., 2016; Gniewosz, Eccles, & Noack, 2015; Jõgi, Kikas, Lerkkanen, & Mägi, 2015; Von Maurice, Dörfler, & Artelt, 2014; by exception, Viljaranta, Tolvanen, Aunola, & Nurmi, 2014, found no significant effect). So, students who perform well in mathematics are likely to value it more in the future.

Although the construct of mathematics anxiety is more affective than motivational, it has been shown to be negatively related to motivational variables (e.g., Bong, Cho, Ahn, & Kim, 2012) and to mathematics achievement (Hembree, 1990; Ma, 1999; for the sake of readability, we refer to mathematics anxiety as one of the motivational variables in our study). Mathematics anxiety refers to feelings of worry, fear and tension which arise when engaging in mathematical activities (Suinn & Winston, 2003) and is theorised to be provoked by frequent failure to understand or perform mathematics tasks. Indeed, meta-analyses have reported a moderate negative correlation between mathematics anxiety and achievement (Hembree, 1990; Ma, 1999) and one cross-sectional study showed that lower achievement had a strong effect on mathematics anxiety (Birgin, Baloğlu, Çatlıoğlu, & Gürbüz, 2010). However, longitudinal research is scarce. In one small-scale study, Krinzinger, Kaufmann, and Willmes (2009) found no effect of previous achievement on mathematics anxiety.

The effects of previous achievement on the motivational aspects mentioned above may differ between students, however, due to differences in their prior experiences. For example, (very) low or high achievement might have more pronounced effects on motivation then achievement in the average range. Alternatively, experiencing failure might have more profound effects on motivation than experiencing success. Therefore, the strength of the relation between previous achievement and motivation might differ between students of diverse achievement levels. In addition, the experience of failure may affect certain aspects of motivation more strongly than the experience of success. Perhaps, the experiences of low-achieving students might mostly affect their levels of mathematics anxiety, while high-achieving students' experiences might predominantly affect their perceived value of mathematics tasks.

However, only few studies examined academic achievement level as a potential moderator of the relations between previous achievement and motivation. Regarding perceived competence, one study found that previous mathematics achievement predicted self-efficacy in typically-achieving primary school students, but not in low-achieving students (Jungert et al., 2014). High-achieving students were not specifically considered in that study and we did not find other studies comparing this relation in students of diverse achievement levels in primary school. We did find two studies comparing different achievement-based tracks in secondary school. One of these studies (Möller et al., 2014) showed that the effect of previous achievement on self-concept was larger for students in the academic track than for students in the vocational track, but only when grades (rather than standardised achievement tests) were used as the achievement indicator. The second study (Van der Beek, Van der Ven, Kroesbergen, & Leseman, 2017) found that the effects of previous achievement on self-concept were similar across three achievement tracks of Dutch secondary schools. However, the situation of tracked students (in separate classes and often even in separate schools) is quite different from primary school in which students of the full range of achievement levels are placed in heterogeneous classrooms. Regarding task value, we found no studies comparing students of diverse achievement levels. One study did compare students of low versus typical general ability levels and found that previous mathematics achievement was a significantly stronger predictor of task value for low-ability students (Jõgi et al., 2015). Regarding mathematics anxiety, Krinzinger et al. (2009) found no indications that the relation between previous achievement and mathematics anxiety differs between low-achieving and typically-achieving students. In that study, however, the relation between achievement and mathematics anxiety was non-significant in both groups. Summing up, while some studies found no differences between students of diverse achievement levels, other findings suggest that previous achievement may affect perceived competence more in typically or high-achieving students, while previous achievement may affect task value more in lower achieving students. However, hardly any studies have compared students of the full range of achievement levels within heterogeneous primary school classrooms.

1.2. How motivation affects subsequent achievement

As indicated earlier, the relations between aspects of motivation and achievement are theorised to be reciprocal. High perceived competence (i.e., self-efficacy and self-concept) as well as high task value are supposed to promote adaptive learning behaviours such as persistence, which should have a positive effect on future achievement (Marsh & Martin, 2011; Wigfield & Eccles, 2000). In contrast, mathematics anxiety is theorised to be associated with worrisome thoughts (taking

[1] Throughout this article, we use the term longitudinal to refer to studies with at least two measurement occasions (enabling statistical control for previous achievement), to distinguish these from cross-sectional studies in which motivation and achievement data were collected at a single timepoint.

away attention from the calculation process) and avoidance behaviour (reducing the amount of practice), which is theorised to have a negative influence on mathematics performance (Krinzinger et al., 2009). Thus, motivation is supposed to have an effect on subsequent achievement, after controlling for previous achievement. Moreover, given the hypothesised effects of previous achievement on motivation, motivation is supposed to mediate the relation between previous and subsequent achievement.

Previous studies have provided multiple indications that perceived competence predicts subsequent achievement (Valentine et al., 2004). In the domain of mathematics, small to moderate positive effects on achievement have been reported for both self-concept (e.g., Chen et al., 2013; Kriegbaum et al., 2015; Niepel, Brunner, & Preckel, 2014) and self-efficacy (e.g., Fast et al., 2010; Jungert et al., 2014; Kriegbaum et al., 2015) after controlling for previous achievement. By exception, Viljaranta et al., 2014) found no significant effect of self-concept on subsequent mathematics achievement.

The effects of task value on subsequent mathematics achievement seem to be rather limited (after controlling for previous achievement). Three longitudinal studies found no significant effects (Garon-Carrier et al., 2016; Jõgi et al, 2015; Viljaranta et al., 2014), whereas another study found a significant but very small effect of task value on subsequent achievement in secondary school (Kriegbaum et al., 2015). This suggests that task value does not necessarily enhance future achievement.

While meta-analyses based on cross-sectional research reported moderate negative correlations between mathematics anxiety and mathematics achievement in elementary and secondary school students (Hembree, 1990; Ma, 1999), studies in which mathematics anxiety is tested as a predictor of subsequent achievement (or with control for previous achievement) are very scarce. Two studies in the early primary grades found no effect of previous mathematics anxiety on basic addition and subtraction tasks after controlling for previous achievement (Krinzinger et al., 2009; Vukovic, Kieffer, Bailey, & Harari, 2013). Vukovic et al. (2013) did find a moderate negative effect on more complex application tasks, but only for students with above-average working memory skills. Cross-sectional research has provided indications that the relation between mathematics anxiety and achievement seems to be moderated by the working memory (WM) load of the strategies used to solve the task, with stronger relations for tasks and strategies requiring high WM capacity (Ramirez, Chang, Maloney, Levine, & Beilock, 2016; Ramirez, Gunderson, Levine, & Beilock, 2013; Wu, Barth, Amin, Malcarne, & Menon, 2012). A possible explanation is that mathematics anxiety places an additional burden on WM, thus interfering more with strategies which already tax WM (Ashcraft, 2002; Ramirez et al., 2016). Remarkably, the negative effects of mathematics anxiety seem to be stronger for students with *high* WM capacities, probably due to their tendency to use WM-intensive strategies (Ramirez et al., 2016, 2013). Given these indications for a potential interaction between mathematics anxiety and working memory, we included working memory in our study to test this interaction in a longitudinal framework.

The effects of motivation on subsequent achievement described above may also differ between students of diverse achievement levels. First, high motivation in general might be especially beneficial for subsequent achievement in low-achieving students, who might need more persistence to reach an adequate achievement level. In line with this idea, a study by VanZile-Tamsen and Livingston (1999) showed that a positive motivational orientation (including self-efficacy and task value) was more strongly related to self-regulated learning strategies in low-achieving students than in high-achieving students. Such positive learning behaviours, provoked by a positive motivational orientation, may in turn enhance achievement. Second, the relative importance of various aspects of motivation might differ depending upon achievement level. For example, self-efficacy might be relatively more important for one achievement group whereas task value might be relatively more important for another achievement group.

Some of the previously mentioned studies about potential differences between students of diverse achievement levels also examined the effects of motivation on subsequent achievement. Jungert et al. (2014) found that self-efficacy predicted subsequent achievement in typically achieving students, but not in low-achieving students. In contrast, Möller et al. (2014) found no significant effect of self-concept either in the vocational or in the academic track of secondary school. For task value, Jõgi et al. (2015) found no significant effects on subsequent achievement in low-ability or typical-ability students. For mathematics anxiety, found no significant effects of mathematics anxiety on subsequent achievement either in low-achieving students or in typically-achieving students (Krinzinger et al., 2009). So, previous findings about differences between students of diverse achievement levels are very scarce but the study by Jungert et al. (2014) provides an initial indication that the effect of self-efficacy on subsequent achievement may vary depending upon achievement level.

1.3. Research questions and hypotheses

Previous studies have already provided many insights into the relations of self-efficacy, self-concept, task value, and mathematics anxiety with achievement, despite some inconsistencies in the results. However, little is known about whether these relations are similar or different for students of diverse achievement levels. The few available studies were mostly based on secondary school students (Möller et al., 2014; Van der Beek et al., 2017) or small samples (Jungert et al., 2014; Krinzinger et al., 2009) and did not consider the full range of achievement levels of students within heterogeneous primary school classrooms. In contrast to secondary school in which students are typically placed in separate classrooms or schools based on achievement level (e.g., a vocational track versus an academic track), primary school classrooms are very diverse and include both (very) low-achieving students as well as (very) high-achieving students. Moreover, the importance of educational experiences during primary school is highlighted by the repeatedly observed trend that motivation for mathematics (Gottfried et al., 2007; Wigfield & Eccles, 2000) and mathematics achievement (Gottfried et al., 2007) already show a significant decline in the course of primary school. Therefore, more studies that differentiate between primary school students of multiple achievement levels (e.g., low-achieving, average-achieving, high-achieving) are needed. Furthermore, most of the available studies have investigated different aspects of motivation in isolation. Since previous studies indicate that the relations between various aspects of motivation and achievement are also dependent on the other motivational aspects included in the model (Spinath, Spinath, Harlaar, & Plomin, 2006) it is necessary to include multiple aspects of motivation simultaneously when investigating the relations between motivation and achievement.

In the current study, we examined the relations between several aspects of motivation (i.e., self-efficacy, self-concept, task value, and mathematics anxiety) and mathematics achievement in heterogeneous primary school classes. We examined both the effects of previous achievement on motivation and the effects of motivation on subsequent achievement, including the potential moderation of these effects by student achievement level. Working memory was included as a covariate since it is an important predictor of mathematics achievement (Friso-Van den Bos, Van der Ven, Kroesbergen, & Van Luit, 2013), with stronger effects on subsequent achievement than general intelligence (Alloway & Alloway, 2010). In addition, we examined whether the effect of mathematics anxiety on achievement was moderated by working memory level. Based on the literature discussed in this introduction, we hypothesised that previous mathematics achievement would positively predict self-efficacy, self-concept, and task value and negatively predict mathematics anxiety. Regarding the effects of motivation on subsequent achievement, we predicted that self-efficacy and self-concept would predict subsequent achievement and that task value would not predict subsequent achievement. For mathematics anxiety, we expected a negative effect but only for students with high working memory capacity due to the interaction between mathematics and working memory described in the literature. Finally, we expected indirect effects of previous achievement on subsequent achievement through the motivational variables. That is, we expected that the motivational variables that were hypothesised to be predicted by previous achievement as well as to predict subsequent achievement would partially mediate the relation between previous and subsequent achievement.

Furthermore, we explored the idea that the strength of these relations between motivation and achievement might differ between students of diverse achievement levels. Given the scarce literature about the potential moderation of the relations between achievement and motivation by achievement level, we did not make specific predictions regarding *how* these effects might differ between students of diverse achievement levels.

2. Method

2.1. Participants

Data were collected in the context of the large-scale project (anonymised for review procedure; see also Prast, van de Weijer-Bergsma, Kroesbergen, & Van Luit, 2018). Thirty-two schools spread across the Netherlands volunteered to participate in this project about differentiation in primary mathematics education.[2] The schools were diverse in terms of school size (*M* = 209 students per school, range 52–550) and mathematics curriculum used. The sample consisted of 4306 students (50.7% male) nested in 184 classes (mean class size = 23 students) from grade 2 through 6. All grade levels were equally represented with about 20% of the sample in each grade level. Mean age at the beginning of the study was 9.45 years (*SD* = 1.53).

2.2. Measures

2.2.1. Mathematics achievement

Mathematics achievement was measured using two types of standardised school achievement tests: the Cito mathematics tests (Janssen, Scheltens, & Kraemer, 2005) and the Arithmetic Tempo Test (ATT; De Vos, 1992). The Cito mathematics tests are national Dutch tests which are commonly administered at the middle and end of each schoolyear to monitor students' progress in mathematics throughout primary school. For each grade level, different versions with developmentally appropriate tasks for both the middle and end of the schoolyear have been developed. In all versions, five main domains are covered: (a) numbers and number relations, covering the structure of the number line and relations between numbers, (b) addition and subtraction, (c) multiplication and division, (d) complex mathematics applications, often involving multiple mathematical manipulations, and (e) measuring (e.g., weight and length). From mid grade 2 to mid grade 6, the following domains are added successively: (f) estimation, (g) time, (h) money, (i) proportions, (j) fractions, and (k) percentages. Content of the tests is based on the core curriculum goals as determined by the Dutch Ministry of Education, Culture and Science. Construct validity is shown by the high correlations between latent mathematics ability measured with subsequent tests over the years (ranging from .75 to .96). The reliability coefficients of the different versions range from .91 to .97 (Janssen, Verhelst, Engelen, & Scheltens, 2010). Based on the means and standard deviations for each grade-level test in a nationally representative sample (Keuning et al., 2015), the scores on each grade-level test were converted into z-scores (0 = an average score compared to the national norms for students in that grade).

The Arithmetic Tempo Test (ATT; De Vos, 1992) is a standardised test frequently used in Dutch and Flemish education to measure fluency in mathematics, specifically arithmetic. Its psychometric value has been established in a sample of 10,059 Flemish children (Ghesquière & Ruijssenaars, 1994). Five sets of 40 formal mathematics problems are presented in one column each for addition (+), subtraction (−), multiplication (×), division (÷), and a mixture of the four domains (+, −, ×, ÷). In each set, children should solve as many problems as possible within 1 min. All problems consist of two-operand equations with an outcome smaller than 100 and both operands ranging between 0 and 90. Children in grade 2 are only required to complete the addition and subtraction columns since multiplication and division are introduced after grade 2. The total score of the ATT consists of the number of items correctly solved across all columns (for students of grade 3 through 6) or across the first two columns (for students of grade 2). To make the scores comparable across grades, we transformed the raw total scores into z-scores expressing the achievement level of individual students relative to other students in the same grade in our sample. Test-retest reliability of the ATT (ρ = .84 to .87, p < .001 after 4 months) and convergent validity in terms of a strong correlation of the ATT with the Cito mathematics tests (ρ = .74, one-sided p < .001) have been established in a previous study (Van de Weijer-Bergsma, Kroesbergen & Van Luit, 2015). In the current study, the comprehensive Cito mathematics tests, which were specifically designed to track the development of students' mathematical competence over time, were used to examine the relations between motivation and achievement over time. The ATT was used to investigate whether these relations differed between students of diverse achievement levels (as measured with the ATT; to avoid using the same variable both as a predictor of motivation and as a moderator of the relation between achievement and motivation).

2.2.2. Motivation

Motivation for mathematics was assessed with the Mathematics Motivation Questionnaire for Children (MMQC; Prast, Van de Weijer-Bergsma, Kroesbergen, & Van Luit, 2012). This self-report questionnaire was designed to measure several aspects of motivation for mathematics in primary school students and includes 24 items about self-efficacy (6 items), self-concept (6 items), task value (7 items), and mathematics anxiety (5 items). All items are rated on the following four-point scale: 1 = NO! (strongly disagree), 2 = no (disagree), 3 = yes (agree), 4 = YES! (strongly agree). Subscale scores are computed by averaging the scores on all items belonging to each subscale (self-efficacy, self-concept, task value and mathematics anxiety). The self-efficacy items concern students' perceived ability to perform mathematics-related tasks. Since the questionnaire was designed for a broad range of grade levels, the questions do not refer to specific mathematical content but to mathematics tasks in general, e.g., "When the teacher explains the first sum, can you do the next sums without help?". In the self-concept items, students are asked to evaluate their own competence in mathematics, e.g., "Are you good at mathematics?". For task value, most items measure the intrinsic or interest value component of task value (e.g., "Do you enjoy doing mathematics?"), but the questionnaire also includes one item each about utility value ("Does it seem handy to you to be good at mathematics?") and personal value ("Do you find mathematics important?"). The mathematics anxiety items concern anxious thoughts and feelings during the mathematics lesson, e.g., "Are you afraid to make mistakes during the mathematics lesson?".

A confirmatory factor analysis had a good fit: *RMSEA* = 0.057, *CFI* = 0.978, *TLI* = 0.975. The chi-square test was significant (χ^2 (246) = 3568.05, *p* < .001), which was expected given the large sample size. All items loaded on their designated factors (range 0.68 –

[2] In ten of the schools of the current sample, teachers participated in a professional development programme about differentiated mathematics education (Prast et al., 2018). The remaining 22 schools were in a control condition. We checked whether the results of the current study were similar for students in experimental and control schools. This was the case, so experimental schools were retained in the sample.

0.95). Only the factor loadings of the two task value items about personal value (0.44) and utility value (0.49) were somewhat low, but these items were retained since they did represent meaningful aspects of task value in addition to the other items which assessed interest value. Moreover, the internal consistency of the subscale including all task value items was good: $\alpha = .87$. The other subscales also had a good internal consistency (self-efficacy: $\alpha = .81$; self-concept: $\alpha = .91$; mathematics anxiety: $\alpha = .84$). We investigated the test-retest reliability of the MMQC in a sample of 75 students with a one-week interval, with good results: reliability coefficients ranged from $r = .82$ for self-concept to $r = .93$ for task value.

2.2.3. Working memory

Working memory was measured to be included as a covariate and to test a potential interaction between WM and mathematics anxiety. The Lion game is a visual–spatial complex span task suitable for self-reliant online administration (Van de Weijer-Bergsma, Kroesbergen, Prast, & Van Luit, 2015). Students are presented with a 4 × 4 matrix on the computer screen. In each trial, eight lions of different colours are consecutively presented at different locations in the matrix. Students should remember the last location where a lion of a certain colour has appeared. The Lion game consists of five levels in which working memory load is manipulated by increasing the number of lions (one through five) that students should remember. A mean proportion correct score indicating the proportion of lions recalled in the correct serial position was calculated. To control for the linear and quadratic effects of age, ageresidualised scores were created by regressing the proportion correct score on age and age-squared and saving the unstandardised residuals. The Lion game has demonstrated very good internal consistency ($\alpha = .90$; Van de Weijer-Bergsma et al., 2015). In addition, the Lion game has been shown to correlate ($r = .51 - .59$, $p < .001$) with the individually administered Automated Working Memory Assessment (Alloway, Gathercole, Kirkwood, & Elliott, 2008) and to predict subsequent mathematics achievement ($\beta = .15$, $p < .001$; Van de Weijer-Bergsma et al., 2015).

2.3. Procedure

The classroom teacher administered the Cito mathematics tests as part of the standard national achievement testing procedure in June 2012 (T1) and February 2013 (T3) and the ATT in September 2012 (T2). The motivation questionnaire was group-administered in the classroom under supervision of a research assistant at T2. In grades 2 and 3, the research assistant read each question aloud, after which the students wrote down their answer. In grades 4 through 6, students completed the questionnaire independently after receiving instructions. The Lion game was administered online at T2: teachers were asked to assign the task and monitor that all students completed the task self-reliantly.

2.4. Data analysis

Data were analysed in M*plus* (version 7.3, Muthén & Muthén, –1998, 2012) using structural equation modelling. First, we developed an overall model for the total sample in which the motivational variables were modelled as mediators between previous and subsequent mathematics achievement (as measured with the Cito mathematics tests). Since models with latent motivational variables were computationally too complex (models did not converge), we worked with the manifest subscale scores of the motivation questionnaire. Fig. 1 represents the basic mediation model which was tested in Model 1. Path *c* represents the stability effect of previous achievement on subsequent mathematics achievement. The *a*-paths represent the effects from previous achievement on motivation. The *b*-paths represent the effects from motivation on subsequent achievement. The motivational variables mediate between previous and subsequent achievement if the indirect effect *ab* (the product of paths *a* and *b*) is significant. This general model was refined by checking whether self-efficacy and self-concept should be combined into a single perceived competence variable (Model 2) and by adding working memory as a covariate (Model 3).

After establishing this general model, we tested whether the relations between motivation and achievement differed between students of diverse achievement levels (all a-paths and b-paths in Fig. 1) and working memory levels (in interaction with mathematics anxiety only). In Model 4, moderation analyses were performed using the continuous z-scores on the ATT as a measure of achievement level. To evaluate potential moderation of the a-paths in Fig. 1, T1 Cito mathematics achievement was multiplied by ATT mathematics achievement and added as a predictor of the motivational variables. To evaluate potential moderation of the b-paths, the motivational variables were multiplied by ATT mathematics achievement and added as predictors of T3 achievement. Similarly, the potential working memory × mathematics anxiety interaction was added as a predictor of T3 achievement. In Model 5, significant moderation effects were followed up with a multiple group analysis where the grouping variable was ATT achievement divided into three categories. To create three approximately equally sized groups, students scoring more than half a standard deviation below the mean were assigned to the low-achieving subsample, students scoring more than half a standard deviation above the mean were assigned to the high-achieving subsample, and students scoring within half a standard deviation around the mean were assigned to the average-achieving subsample. To evaluate whether the relations between achievement and motivation differed significantly across the three achievement subsamples, Wald tests were performed.

Following Hu and Bentler (1999), models with values above .95 for the comparative fit index (CFI) and Tucker-Lewis Index (TLI) and values below .06 and .08 for the root mean squared error of approximation (RMSEA) and the standardised root mean square residual (SRMR), respectively, were judged to have a good fit. In all models, predictor variables were grand-mean centered to facilitate interpretation of the results. Full information maximum likelihood estimation with robust standard errors was used to handle missing data and to correct for nonnormality. To correct for the nesting of students within classes, the *type = complex* option of M*plus* was used. This method ensures that standard errors are corrected for the clustered data structure without building a full multilevel model (McNeish, Stapleton, & Silverman, 2017). M*plus* uses the Huber-White procedure for computing cluster-robust standard errors (Huber, 1967; White, 1980). To calculate indirect effects for the final models, the standardised parameter estimates of the *a* and *b* paths obtained in M*plus* were entered in the Rmediation package (Tofighi & MacKinnon, 2011) which provides 95% confidence intervals for the indirect effects based on the distribution of the product. The fully standardised mediated effect was used as an effect size measure for the indirect effect because of its satisfactory statistical properties and because it was of interest to evaluate the change in standard deviations of the outcome with a one standard deviation increase in the independent variable (Miočević, O'Rourke, MacKinnon, & Brown, 2018).

3. Results

Descriptive statistics are displayed in Table 1. The mean scores on the Cito mathematics tests indicate that the total sample and the average-achieving subsample scored slightly above the national average, whereas the subsamples of low-achieving and high-achieving students scored lower and higher, respectively. Differences between the

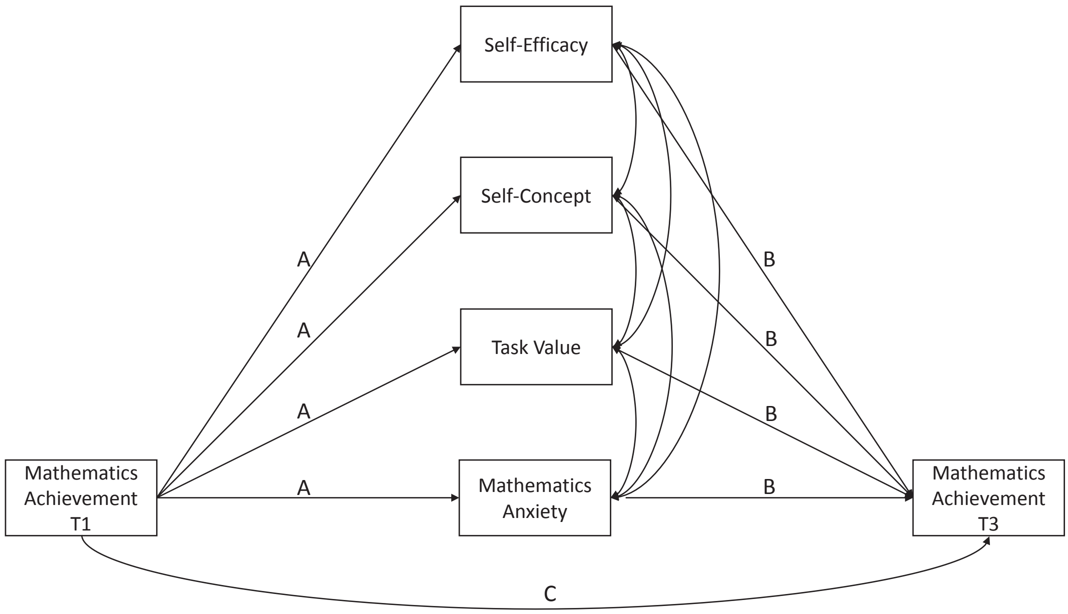

Fig. 1. Conceptual model for Model 1 (basic mediation model).

high-achieving and low-achieving groups were more pronounced on the ATT, which may be explained by the fact that the ATT was used to create the groups. For all motivational variables, the low-achieving subsample scored lower and the high-achieving subsample scored higher compared to the average-achieving subsample. The distributions of the motivational variables were somewhat skewed, with relatively many high scores for self-efficacy, self-concept, and task value and relatively many low scores for mathematics anxiety (but the use of the maximum likelihood robust estimator corrected for this in the subsequent analyses).

Zero-order correlations between the variables are displayed in Table 2. All correlations were significant and in the expected direction. Self-efficacy and self-concept were strongly correlated (r = .80). Moreover, a combined perceived competence subscale representing the average of all self-efficacy and self-concept items had a very high internal consistency (α = .92). This raised the question whether these two constructs were empirically sufficiently distinct to be modelled as separate variables. In the subsequent analyses, we therefore compared a model in which the two variables were modelled separately to a model in which the variables were combined and proceeded with the best-fitting model.

Model 1 tested the basic mediation model represented in Fig. 1. Model 2 was identical to Model 1, except that self-efficacy and self-concept were combined into one variable labelled perceived competence. An overview of all models and their respective fit is provided in Table 3. Both Model 1 and Model 2 were saturated, but Model 2 yielded smaller values on the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), indicating that it had a better fit than Model 1. Notably, in Model 1, self-concept significantly predicted subsequent mathematics achievement (β = .123, $p < .001$), but self-efficacy did not (β = .001, p = .949), which can most probably be explained by multicollinearity of the two variables (see also Marsh, Dowson, Pietsch, & Walker, 2004). For the other parameters, Model 1 and Model 2 displayed similar results (detailed results for all models can be found in Appendix A). Given the indications for a multicollinearity problem in Model 1 and the better fit of Model 2, we pursued the analyses with the combined perceived competence variable.

In Model 2, previous mathematics achievement had a strong positive effect on perceived competence (β = .506, $p < .001$) and a small to moderate positive effect on task value (β = .187, $p < .001$).

Table 1
Descriptive statistics.

	Total sample N = 4306 *M (SD)*	Low-achieving subsample N = 1224[a] *M (SD)*	Average-achieving subsample N = 1452[a] *M (SD)*	High-achieving subsample N = 1202[a] *M (SD)*	Skewness *(SE)*	Kurtosis *(SE)*	% missing
Cito maths T1	0.11 (1.10)	−0.48 (0.97)	0.11 (0.95)	0.77 (1.00)	0.04 (0.04)	0.76 (0.08)	10.6
Cito maths T3	0.07 (1.13)	−0.56 (1.04)	0.06 (0.96)	0.77 (0.98)	−0.02 (0.04)	0.98 (0.08)	6.3
ATT maths T2	0.00 (1.00)	−1.11 (0.48)	−0.02 (0.28)	1.16 (0.54)	0.14 (0.04)	−0.03 (0.79)	9.9
Self-efficacy	3.09 (0.55)	2.82 (0.55)	3.08 (0.51)	3.36 (0.46)	−0.37 (0.04)	0.07 (0.08)	4.6
Self-concept	3.05 (0.74)	2.61 (0.74)	3.05 (0.66)	3.48 (0.53)	−0.63 (0.04)	−0.24 (0.08)	4.6
Task value	3.00 (0.72)	2.76 (0.73)	3.01 (0.68)	3.22 (0.65)	−0.38 (0.04)	−0.72 (0.08)	4.6
Maths anxiety	1.67 (0.67)	1.89 (0.74)	1.67 (0.64)	1.43 (0.52)	1.07 (0.04)	0.65 (0.08)	4.6
Working memory	0.00 (0.16)	−0.03 (0.17)	0.01 (0.15)	0.04 (0.15)	−1.06 (0.04)	1.58 (0.08)	10.9

[a] The achievement subsamples do not add up to the total sample size since students with missing data on the ATT could not be assigned to an achievement subsample.

Table 2
Zero-order correlations.

	Cito maths T1	Cito maths T3	ATT maths T2	Self-efficacy	Self-concept	Task value	Maths anxiety
Cito maths T1							
Cito maths T3	.80**						
ATT maths T2	.50**	.51**					
Self-efficacy	.42**	.41**	.42**				
Self-concept	.52**	.51**	.49**	.80**			
Task value	.19**	.21**	.27**	.45**	.47**		
Maths anxiety	−.33**	−.32**	−.28**	−.56**	−.60**	−.26**	
Working memory	.29**	.32**	.18**	.11**	.15**	.09**	−.08**

** $p < .01$.

Moreover, previous achievement had a moderate negative effect on mathematics anxiety (β = −.334, $p < .001$). Of the motivational variables, only perceived competence had a significant effect on subsequent achievement. This effect was positive as expected, but small in size (β = .115, $p < .001$). Previous achievement had a strong effect on subsequent achievement (β = .737, $p < .001$), indicating temporal stability.

In Model 3, working memory was added as a covariate. This model was no longer saturated and had a good fit. WM had a significant small positive effect on subsequent achievement (β = .092, $p < .001$). The other parameters in the model remained similar after controlling for WM. Model 3 was the final general model (excluding moderators and interactions) and its results are depicted in Fig. 2. In Model 3, the estimated fully standardised indirect effect from previous achievement on subsequent achievement through perceived competence was 0.060 (*SE* = 0.009; $p < .001$; 95% *CI* = [0.043, 0.077]). This indicates that an increase of one standard deviation in previous achievement yields an increase of 0.060 standard deviation on subsequent achievement on the mathematics test through changes in perceived competence, which can be interpreted as a small indirect effect.

In Model 4, achievement level (as measured with the ATT) was evaluated as a potential moderator of the *a* and *b* paths and the working memory × mathematics anxiety interaction was tested. This model had suboptimal fit (see Table 3). The general pattern of results was similar to previous models. In addition, ATT achievement had positive effects on perceived competence and task value, negative effects on mathematics anxiety, and positive effects on subsequent Cito achievement (see Appendix A). Only the effect of previous achievement on perceived competence was significantly moderated by ATT achievement level (β = −.041, $p = .024$). The other potential moderations by ATT achievement, as well as the working memory × mathematics anxiety interaction, were not significant (see Appendix A).

In Model 5, Model 3 was estimated as a multigroup model for low-achieving, average-achieving and high-achieving students to examine *how* the effect of previous achievement on perceived competence, which had been shown in Model 4 to be moderated by achievement level, differed between achievement groups. A visual comparison indicated that the effect of previous achievement on perceived competence was largest in the average-achieving subsample (β = .439, $p < .001$), followed by the high-achieving subsample (β = .390, $p < .001$), followed by the low-achieving subsample (β = .340, $p < .001$). Wald tests indicated that the effect of previous achievement on perceived competence differed significantly only between the average- and high-achieving subsamples (*W* [*df* = 1] = 11.706, $p = .001$). From the numerical values of the paths in the three groups it would be expected that the effect of previous achievement on perceived competence would also differ between the average- and low-achieving subsamples. However, the non-significant Wald test for the comparison of paths in these two groups might be explained by the fact that the Wald test is not only based on effect size, but also on the standard errors of the parameters and their covariance. Parameter estimates for all paths, split by achievement group, are provided in Fig. 2 and Appendix A. While the pattern of results within each achievement group was largely comparable to the findings in the whole sample, the following whole-sample effects did not reach significance within specific achievement groups. First, the effect of previous achievement on task value was not significant in the low-achieving group (β = .053, $p = .076$). Second, the effect of perceived competence on subsequent achievement was not significant in the average-achieving group (β = .040, $p = .115$). Given the latter, perceived competence was not a significant mediator of the effect of previous achievement on subsequent achievement within the average-achieving group (the estimated fully standardised indirect effect was 0.018; *SE* = 0.011; $p = .115$; 95% *CI* = [−.005, .040]). In the low-achieving and high-achieving subsamples, perceived competence was shown to be a significant mediator of the effect of previous achievement on subsequent achievement. The estimated fully standardised indirect effects from previous achievement on subsequent achievement through perceived competence were 0.038 (*SE* = 0.010; $p < .001$; 95% *CI* = [.019, .059]) for the low-achieving subsample and 0.057 (*SE* = 0.015; $p < .001$; 95% *CI* = [.028, .087]) for the high-achieving subsample.

4. Discussion

In this large-scale study, we investigated the effects of previous mathematics achievement on perceived competence, task value, and

Table 3
Overview of models and model fit.

Model	AIC	BIC	χ^2 (df), *p*	RMSEA	CFI	TLI	SRMR
1: as Fig. 1	44720.765	44892.638	Saturated (df = 0)	–	–	–	–
2: self-efficacy and self-concept combined	40843.719	40971.032	Saturated (df = 0)	–	–	–	–
3: plus WM as predictor of maths T3	37129.589	37282.415	5.367 (3), .147	.014	.999	.997	.006
4: plus interactions with achievement level and WM	67594.215	68057.683	270.768 (16), < .001	.064	.940	.859	.035
5: multiple-group as Model 3	31994.461	32445.403	8.262 (9), .508	.000	1.00	1.00	.009

WM = working memory.

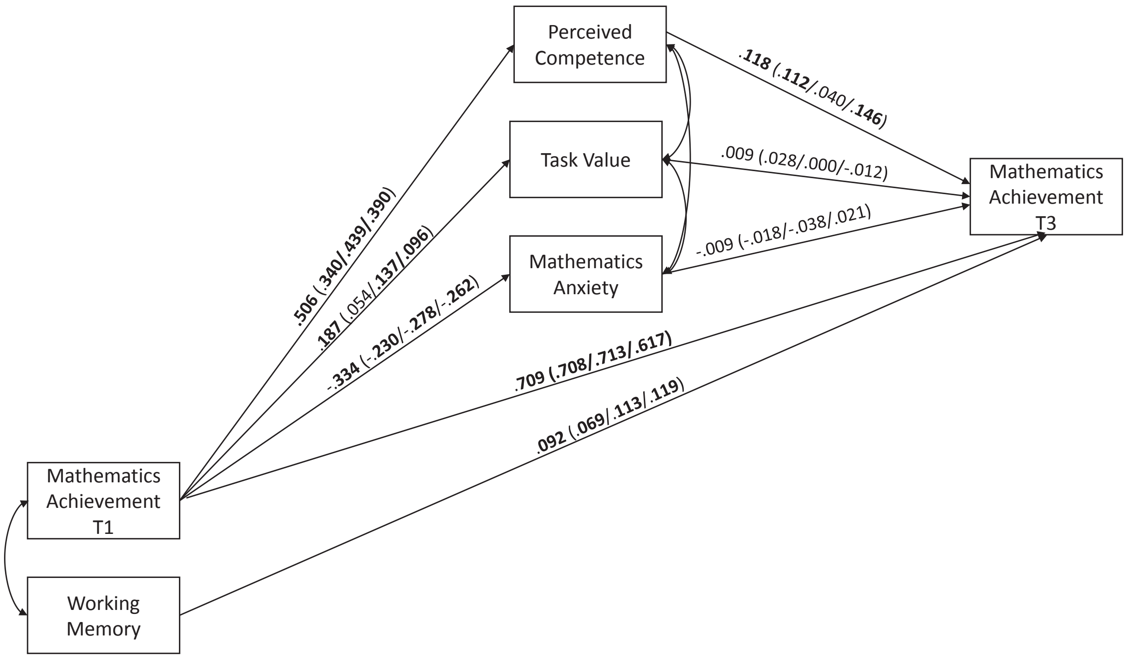

Fig. 2. Final model results for the full sample (Model 3) and, in parentheses, for the achievement subsamples (low-achieving/average-achieving/high-achieving). Estimates printed in bold are significant ($p < .05$).

mathematics anxiety as well as the effects of these motivational variables on subsequent achievement with particular attention for potential differences between students of diverse achievement levels.

4.1. Effects of previous achievement on motivation

As expected based on previous studies (e.g., Birgin et al., 2010; Chen, et al., 2013; Fast et al., 2010; Garon-Carrier et al., 2016; Gniewosz, et al., 2015; Jõgi et al., 2015; Jungert et al., 2014; Ma, 1999; Von Maurice, et al., 2014), previous achievement had positive effects on perceived competence (self-efficacy and self-concept combined) and task value and negative effects on mathematics anxiety. While our findings are in line with most of the literature they also extend it, since this was the first study to examine the effects of previous mathematics achievement on both perceived competence, task value and mathematics anxiety simultaneously in primary school. Our results show that the effects continued to exist besides each other and were generally strongest for perceived competence, followed by mathematics anxiety, followed by task value. It should be kept in mind that these effects in the statistical sense are not equal to causal effects, since we did not control for previous motivation. For example, perceived competence is likely to be influenced not only by previous achievement but also by previous perceived competence, which is correlated with achievement at that previous time point.

We found both similarities and differences between students of diverse achievement levels regarding the effect of previous achievement on motivation. The general pattern of effects was similar across groups. The interaction analysis did reveal that the effect of previous achievement on perceived competence was significantly moderated by current achievement (as measured with the ATT). The subsequent multiple group model demonstrated that this effect, while significantly positive in all groups, was larger in average-achieving students compared to high-achieving students (and, judging by the effect sizes, perhaps also compared to low-achieving students but this difference was not significant according to the Wald tests). The conceptual difference between these two models should be kept in mind: the interaction analysis (Model 4) evaluated whether the effect of previous achievement on perceived competence varied across the full range of achievement levels, whereas the multiple group model (Model 5) evaluated the effect of previous achievement on perceived competence *within* each achievement group. Students may tend to compare their own achievement to the achievement of the whole class (as in the interaction analysis) rather than to a subsample of students with a similar achievement level (as in the multiple group model). For high-achieving students, for example, it might be more meaningful to evaluate their achievement compared to the whole class (i.e., high-achieving) than to other high-achieving students (e.g., low-achieving compared to other high-achieving students). While average-achieving students might also compare themselves to the whole class rather than to other average-achieving students, the results of these two methods may correspond more closely since the class-average achievement will generally be close to the average achievement within the average-achieving subsample. This might explain the stronger effects for average-achieving students in the multiple group model. The stronger effects for average-achieving students are partly in line with the study by Jungert et al. (2014), who found that previous achievement predicted perceived competence only in average-achieving students but not in low-achieving students. Our study also found stronger effects in average-achieving students, but the effects were still significant and quite substantial in low-achieving students. Furthermore, the typically achieving group in Jungert et al. (2004) seems to have included both average-achieving and high-achieving students, whereas high-achieving students were considered separately from average-achieving students in the current study. Based on our study, we can only speculate about reasons for this seemingly stronger effect of previous achievement for average-achieving students and future research is necessary to investigate the mechanisms behind this in more detail.

The effects of previous achievement on task value and mathematics anxiety were not significantly moderated by achievement level, as indicated by the interaction analysis. The multiple group model generally showed similar patterns for each achievement group. Only the effect of previous achievement on task value did not reach significance in the low-achieving group, although it was similar in direction (β = .054, $p = .076$). Thus, differences in achievement within the low-achieving group did not have a significant effect on task value within the low-achieving group. The reduced range of achievement levels within each subsample as compared to the total sample may explain why some of the total-sample effects did not reach significance within each subsample. Across the full range of achievement levels, however, previous achievement had a positive effect on task value and a negative effect on mathematics anxiety.

In sum, while we found subtle differences between students of diverse achievement levels, the effects of previous achievement on motivation seem to be largely similar across achievement levels. This study provides no indications that the effects of low or high previous achievement are more profound than the general effects of previous achievement on motivation. In fact, the effect of previous achievement on perceived competence seem to be somewhat stronger in average-achieving students, although more research would be necessary to replicate and explain this finding. Neither do our data suggest that previous achievement is more strongly related to specific motivational variables, compared to other motivational variables, depending on the achievement level of the students. Across the full range of achievement levels within primary school, previous achievement had the strongest effect on perceived competence, followed by mathematics anxiety, followed by task value.

4.2. Effects of motivation on subsequent achievement

Regarding the effects of motivation on subsequent achievement, only perceived competence significantly predicted subsequent achievement. This corresponds with previous studies in which perceived competence was a stronger predictor of subsequent achievement than other motivational variables (Bong et al., 2012; Kriegbaum et al., 2015; Spinath et al., 2006). Those previous findings were mainly obtained with older students (late elementary school or secondary school), whereas our study shows that the relative importance of perceived competence also holds in (early) primary school. In line with our hypothesis and previous findings (e.g., Jungert et al., 2014), perceived competence partially mediated between previous and subsequent achievement, with a small but significant indirect effect.

Task value and mathematics anxiety did not predict subsequent achievement, which might be explained by the inclusion of previous achievement as well as multiple motivational variables in the model. The zero-order correlations (reported in Table 2) showed that both task value ($r = .21$) and mathematics anxiety ($r = -.31$) were significantly related to subsequent achievement. However, these relations were no longer significant in the full model in which the effects of motivation on achievement were controlled for previous achievement and modelled besides the effects of other motivational variables. For task value, this lack of effects was in line with previous studies in which the effects of task value were controlled for previous achievement or modelled besides other motivational variables (Bouffard, Marcoux, Vezeau, & Bordeleau, 2003; Garon-Carrier et al., 2016; Spinath et al., 2006; although Kriegbaum et al. (2015) found a significant but very small effect in secondary school). This does not necessarily mean that task value has no effect on subsequent achievement when modelled as a single predictor, since the substantial correlation between task value and perceived competence may cause a reciprocal suppression effect (Plante, De la Sablonnière, Aronson, & Théorêt, 2013). As explained by Plante et al. (2013), it is possible that the variance which task value shares with perceived competence has a positive effect on subsequent achievement, while the unique variance of task value which does not overlap with perceived competence has no or even a negative effect on achievement. For example, high task value might be stressful when it is not coupled with high perceived competence: students with this combination might feel the need to achieve well in mathematics, but might not feel able to do so. The findings of our study and previous studies (Bouffard et al., 2003; Garon-Carrier et al., 2016; Plante et al., 2013; Spinath et al., 2006) suggest that valuing a subject is not, by itself, enough to enhance achievement. We speculate that, while task value may trigger students to engage in an activity, it needs to be coupled with perceived competence (which may arise over time if the student experiences success during the activity) to potentially enhance achievement.

Regarding mathematics anxiety, we found no effect on subsequent achievement. We had predicted that mathematics anxiety would have a negative effect, but only for students with high WM capacity. However, this hypothesis was based on previous studies that typically did not control for previous achievement and did not include other motivational variables in the model. When perceived competence and mathematics anxiety are simultaneously modelled as predictors of subsequent achievement, a similar reciprocal suppression effect might come into play. The unique variance of mathematics anxiety which does not overlap with perceived competence might be interpreted as a student's general inclination towards anxiety, regardless of the student's perceived competence in mathematics. Perhaps, this anxiety is not very harmful as long as it is not coupled with low perceived competence, since students with high perceived competence might have little reason to be anxious specifically for mathematics. Recent research suggests that mathematics anxiety is an effect of low perceived competence (Van der Beek et al., 2017). Another possible explanation for the lack of effects of mathematics anxiety on subsequent achievement in the current study is that we used a longitudinal design with control for previous achievement. In contrast, most previous studies about mathematics anxiety used cross-sectional designs in which mathematics anxiety and achievement were measured at the same timepoint. Perhaps, for anxiety, concurrent effects could be more relevant than longitudinal effects, since anxiety is supposed to interfere directly with performance during testing. Previous longitudinal studies (Krinzinger et al., 2009; Vukovic et al., 2013) also found no general effect of mathematics anxiety on subsequent achievement after controlling for previous achievement. Vukovic et al. (2013) did find a longitudinal effect, but only on application problems and only for students with high WM capacity. In our study, this interaction with WM was not replicated (despite the use of application problems in the mathematics achievement test). More research is necessary to clarify in which situations mathematics anxiety interacts with WM.

Regarding potential differences between students of diverse achievement levels, we found that these effects were largely similar across achievement levels. The interaction analysis revealed no significant moderation of the effect of any of the motivational variables on achievement across the full range of achievement levels. The multiple group analysis demonstrated a similar pattern of effects across groups, with one exception: the effect of perceived competence on subsequent achievement was no longer significant within the average-achieving group. Thus, differences in perceived competence *within* the average-achieving group did not predict subsequent achievement. This may again be partly explained by a reduced variance of perceived competence within the average-achieving subsample compared to the total sample. However, the variance in perceived competence within the high-achieving group ($SD = .47$) was even smaller than in the average-achieving group ($SD = .55$), and nevertheless differences in perceived competence within the high-achieving group did predict subsequent achievement. Thus, it may be that differences in perceived competence within the low-achieving or high-achieving range are more relevant than differences in perceived competence within the average-achieving range. In the full sample, however, the effect of perceived competence on subsequent achievement was not moderated by achievement level. This indicates that the effect of perceived competence is also relevant for average-achieving students, provided that their perceived competence is evaluated relative to students of the full range of achievement levels. The effects of mathematics anxiety and task value were not moderated by achievement level and were not significant in any of the achievement groups. Thus, it is not the case that these aspects of motivation are only related to subsequent achievement in one particular achievement group (which might have been an explanation for the lack of effects in the total sample).

Summing up, we explored the ideas that the importance of a positive motivational orientation in general, or the relative importance of specific aspects of motivation, might vary depending on achievement level. Our data provide little support for either of these ideas, although the effects of perceived competence seem to be somewhat smaller *within* the average-achieving group. We did find that perceived competence was generally more strongly related to subsequent achievement than the other motivational variables. Perceived competence was the only motivational variable that predicted subsequent achievement in the full range of achievement levels as well as within the low-achieving and high-achieving subsample.

4.3. Implications, limitations and directions for future research

This study has shown that perceived competence makes a unique contribution in the prediction of future achievement, over and above the effects of previous achievement, working memory, task value and mathematics anxiety. This pattern holds for students across the full range of achievement levels in heterogeneous primary school classrooms as well as within subsamples of low-achieving and high-achieving students. Moreover, we found support for indirect effects of previous achievement on subsequent achievement through changes in perceived competence, implying that changes in perceived and actual competence may strengthen each other in a cycle of either negative or positive effects. These results imply that fostering perceived competence might be a promising way to enhance achievement for students of all achievement levels. However, this conclusion should be drawn with care since our results also indicate that actual achievement is an important source of perceived competence. It does not seem to make sense to foster unrealistically high perceived competence, but it might be helpful to create situations in which students can experience mastery. This might enhance students' perceived competence and, in turn, adaptive learning behaviours and subsequent achievement. Interestingly, in a study in which the success rate of solving mathematics problems was experimentally manipulated (Jansen et al., 2013), students who experienced more success did not show higher perceived competence (contrary to expectations) but did attempt to solve more problems and increased more in performance compared to students who experienced less success. One opportunity for experiencing success might be to give specific mastery-oriented feedback when a student performs a task successfully ("You really know how to solve this kind of sums now, don't you?"). Another opportunity might be to adapt the challenge level of mathematics tasks to students' current level of understanding to ensure that the tasks are challenging but realistic for all students. One currently popular way to enable all students to work in their zone of proximal development (in which success is just within reach) is differentiated instruction, an educational approach in which goals, instruction and practice are adapted to students' educational needs based on current achievement level (Prast, Van de Weijer-Bergsma, Kroesbergen, & Van Luit, 2015; Roy, Guay, & Valois, 2013). In this way, especially low-achieving students might experience less failure and more success, which might have positive effects on perceived competence. On the other hand, low-achieving students might start to feel less confident about their own competence when they are aware that they receive additional instruction or work on easier tasks than their peers. Given the demonstrated importance of perceived competence, the potential positive and negative effects of differentiated instruction on the perceived competence of students of diverse achievement levels should be examined in future research.

Future research might also spend more attention on *how* achievement and motivation might influence each other in general and differentially in students of diverse achievement levels. In the current study, previous achievement was measured with a standardised achievement test. Students are likely to have considered other sources of information as well in their estimation of their own mathematical competence, including report card grades and daily experiences in mathematics lessons. In experimental designs, achievement level might be manipulated (by adapting the difficulty level of the tasks) and students might be provided with either correct or incorrect information regarding their own performance to examine how the relation between achievement and perceived competence might differ between students of diverse achievement levels. Similarly, the processes behind the effects of perceived competence on subsequent achievement might be examined using experimental manipulation.

Developmental processes also require more attention in future research. A limitation of the current study is that its timeframe was limited to three measurement occasions spread over half a year. The processes within the timeframe of our study are likely to be influenced as well by educational experiences before the beginning of the study. Especially in the higher grades, previous achievement is confounded with previous educational quality and motivation for mathematics. There are indications that the relations between motivation and achievement also develop and change over the course of primary school, with stronger relations as children grow older (Denissen et al., 2007; Weidinger, Steinmayer, & Spinath, 2018). In addition to such developmental effects, between-grade differences might also exist due to the increasing depth and breadth of mathematical content depending on grade level (e.g., the sequential introduction of addition, subtraction, multiplication and division). Future studies could follow students from the very beginning of (preparatory) mathematics education onwards and use cross-lagged designs to track the development of students' motivation and achievement over a longer period of time. This would enable stronger causal inferences and provide more insight into developmental and grade-based changes in these relations.

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Appendix A. Detailed results for all models

Table A1
Standardised results of Model 1 with self-efficacy and self-concept as separate variables ($N = 4297$).

Parameter	Estimate *(SE)*
Predictors	
T1 Ach. → SE	.425** (.019)
T1 Ach. → SC	.524** (.017)
T1 Ach. → TV	.186** (.019)
T1 Ach. → MA	−.334** (.014)
T1 Ach. → T3 Ach.	.732** (.013)
SE → T3 Ach.	.001 (.019)
SC → T3 Ach.	.123** (.020)
TV → T3 Ach.	.011 (.013)
MA → T3 Ach.	−.007 (.013)
Correlations	
SE with SC	.755** (.008)
SE with TV	.413** (.017)
SE with MA	−.493** (.014)
SC with TV	.449** (.018)
SC with MA	−.529** (.014)
TV with MA	−.212** (.018)

T1 Ach. = mathematics achievement at T1, T3 Ach. = mathematics achievement at T3, SE = self-efficacy, SC = self-concept, TV = task value, MA = mathematics anxiety. For parsimony, means (close to 0 due to centering) and variances are omitted from the table.

** $p < .01$.

Table A2
Standardised results of Models 2 through 5.

Parameter	Model 2 $N = 4297$ Estimate (*SE*)	Model 3 $N = 4306$ Estimate (*SE*)	Model 4 $N = 3878$ Estimate (*SE*)	Model 5 Low-achieving $n = 1224$ Estimate (*SE*)	Model 5 Average-achieving $n = 1452$ Estimate (*SE*)	Model 5 High-achieving $n = 1202$ Estimate (*SE*)
T1 Ach. → PC	.506** (.018)	.506** (.018)	.365** (.021)	.340** (.034)	.439** (.024)	.390** (.030)
T1 Ach. → TV	.187** (.019)	.187** (.019)	.087** (.020)	.054 (.030)	.137** (.030)	.096** (.030)
T1 Ach. → MA	−.334** (.014)	−.334** (.014)	−.266** (.018)	−.230** (.030)	−.278** (.024)	−.262** (.031)
T1 Ach. → T3 Ach.	.737** (.013)	.709** (.014)	.663** (.016)	.708** (.023)	.713** (.020)	.617** (.029)
WM → T3 Ach.	n/a	.092** (.013)	.091** (.014)	.069* (.028)	.113** (.020)	.119** (.026)
PC → T3 Ach.	.115** (.017)	.118** (.017)	.088** (.019)	.112** (.028)	.040 (.026)	.146** (.037)
TV → T3 Ach.	.013 (.013)	.009 (.013)	.002 (.013)	.028 (.027)	.000 (.021)	−.012 (.024)
MA → T3 Ach.	−.009 (.013)	−.009 (.013)	−.015 (.015)	−.018 (.022)	−.038 (.022)	.021 (.031)
WM × MA → T3 Ach.	n/a	n/a	.006 (.012)	n/a	n/a	n/a
ATT → PC	n/a	n/a	.301** (.021)	n/a	n/a	n/a
ATT × T1 Ach. → PC	n/a	n/a	−.041* (.018)	n/a	n/a	n/a
ATT → TV	n/a	n/a	.223** (.022)	n/a	n/a	n/a
ATT × T1 Ach. → TV	n/a	n/a	−.007 (.016)	n/a	n/a	n/a
ATT → MA	n/a	n/a	−.152** (.019)	n/a	n/a	n/a
ATT × T1 Ach. → MA	n/a	n/a	.026 (.020)	n/a	n/a	n/a
ATT → T3 Ach.	n/a	n/a	.119** (.017)	n/a	n/a	n/a
ATT × PC → T3 Ach.	n/a	n/a	−.011 (.018)	n/a	n/a	n/a
ATT × TV → T3 Ach.	n/a	n/a	−.015 (.014)	n/a	n/a	n/a
ATT × MA → T3 Ach.	n/a	n/a	.005 (.015)	n/a	n/a	n/a

T1 Ach. = Cito mathematics achievement at T1, ATT = Arithmetic Tempo Test achievement level, T3 Ach. = Cito mathematics achievement at T3, PC = perceived competence, TV = task value, MA = mathematics anxiety, WM = working memory. For parsimony, estimated correlations, means (close to 0 due to centering) and variances were omitted from the table.

* $p < .05$.

** $p < .01$.

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