When Do Students Begin to Think That One Has to Be Either a “Math Person” or a “Language Person”? A Meta-Analytic Review

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Abstract

Believing that one is either a “math person” or a “language person” can have important implications for students’ engagement and performance in different activities and for their educational and career choices. One important source of information children use to form such self-relevant motivational beliefs are dimensional comparisons; that is, students engage in intraindividual comparisons of their subjective abilities across domains such as math and language arts when making self-evaluations. Despite their fundamental impact on students’ educational outcomes, our understanding of when dimensional comparisons begin to influence children’s self-perceptions, how this influence might change as children grow older, and whether the pattern varies across different types of motivational beliefs is still limited. A meta-analysis of 142 independent samples, 210,954 participants, and 426 effect sizes showed that the correlations between students’ math- and language-related motivational beliefs decreased from $r = .32$, 95% CI [.26, .37] for Grades 1-4 to $r = -.01$, 95% CI [-.07, .04] for Grades 9-12/13. A meta-regression revealed a significant moderating effect of students’ grade level on the association between students’ math- and language-related motivational beliefs ($b = -.06$, 95% CI [-.06, -.05]), indicating an increasing differentiation in these beliefs. Findings generalized over samples across the world and studies using different research designs and held true for motivational constructs such as ability self-concepts and interests. Our results suggest that dimensional comparisons are involved in the formation of students’ domain-specific motivational beliefs across the childhood and adolescent years and that their relative importance increases over the school years.

Keywords: ability self-concept, interest, motivational beliefs, development, dimensional comparisons

Public Significance Statement: Dimensional comparisons—i.e., intraindividual comparisons of a person’s relative and subjective strengths and weaknesses across different domains—are an important source of information people use to determine what they are good at and what they like. This meta-analysis shows that students’ reliance on dimensional comparisons across the math and verbal domains increases over the school years. The role of dimensional comparisons is strongest in the high school years, a time when students form specialized identities (e.g., a “math person”) and make achievement-related choices with long-term consequences for their educational and career trajectories.

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How good am I at doing this? How much do I like doing that? These questions are related to what psychologists call self-relevant motivational beliefs, including ability self-concepts and interests, i.e., individuals’ subjective beliefs about how good they are at or how much they like a skill-based task or activity. People think about such questions throughout their lives. The answers to these questions are particularly important in the school setting because they can influence whether students want to engage in a given class or academic domain, and thus how students perform in this class or domain (e.g., Cai et al., 2018; Steinmayr & Spinath, 2009). Moreover, they play a critical role in the decision-making process of whether students want to enroll in a specific class if and when enrollment becomes an option, and what college major and occupation students aspire to when these decisions need to be made (e.g., Lauermann et al., 2017; Simpkins et al., 2006; for a review, see Wigfield & Eccles, 2020). However, how do students determine how good they are at or how much they like a given academic domain? How do they come to make distinctions across different subject domains such as math and language arts? And how might these processes change throughout the K-12 school years? Researchers have sought to understand the developmental progression in how children form self-relevant motivational beliefs over time, but our understanding of these processes is still limited.

There are a variety of sources that children and adolescents can use to form motivational beliefs about their abilities and preferences across different academic subjects (e.g., McPartlan et al., 2020; Stipek & Mac Iver, 1989). These sources include input from important socializers such as parents and teachers (Frome & Eccles, 1998; Simpkins et al., 2012), objective performance feedback (Arens et al., 2017; Marsh et al., 2005), social comparisons (i.e., comparing

performances with those of other people; Guo et al., 2018; Ruble et al., 1980), and dimensional comparisons (i.e., comparing performances within themselves across different academic domains; Möller & Marsh, 2013; Schurtz et al., 2014). Developmental psychologists have suggested that the extent to which children and adolescents rely on different sources may change over time due to cognitive development and shifts in the salience of various types of information (Eccles, Arberton, et al., 1993; Higgins & Parsons, 1983; Parsons & Ruble, 1977; Ruble et al., 1980; Stipek & Mac Iver, 1989; Wigfield et al., 2015). For example, students' domain-specific self-concepts of ability become increasingly aligned with their actual performance throughout the school years (Davis-Kean et al., 2008; Weidinger et al., 2018). Such findings provide compelling evidence for the increasing ability of children to integrate performance information with their self-concepts over time and to use social comparative information in forming their perception of own abilities. In addition, children begin to hold different self-perceptions of competence across different achievement domains in the early elementary school years (Eccles, Wigfield, et al., 1993). As a result, dimensional comparisons emerge as a source that children and adolescents can use to form their perception of competence. Previous studies about dimensional comparisons have mainly focused on the impact of such comparative processes on students' ability self-concept formation (Möller & Marsh, 2013). Yet it is understudied how the relative importance of dimensional comparisons versus other sources in forming students' ability self-concepts and related motivational beliefs might change as children progress through the school years. Similarly, we still do not know much about the developmental progression in how children combine all those sources of information to form self-relevant motivational beliefs about their abilities and interests over time.

Within the present study, we focus on the developmental change likely connected with dimensional comparison processes in the ontogeny of students' self-relevant motivational beliefs. If students are primarily using objective information (e.g., test scores) and social comparisons to form their ability self-perceptions in math and language arts, then their math and verbal ability self-concepts should be positively correlated over time. The reason is that students' math and language achievement are strongly positively correlated, and this relation is consistent over age (for meta-analytic reviews, see Möller, et al., 2009, 2020). But if students primarily use dimensional comparisons, their math and language ability self-concepts should be negatively correlated. The reason is that ability in one of the two domains is usually used as a comparative standard against the ability in the other domain (for a review, see Möller & Marsh, 2013). Evidence with adolescents and young adults (e.g., Marsh, 1986; Möller & Köller, 2001) suggests that there is a negative effect of achievement in one domain (e.g., language) on non-corresponding ability self-concepts in contrasting domains (e.g., math). However, the impact of different sources of information on students' self-perceptions is likely to vary over age depending on the students' capacities and motivation to use different types of information. Our goal is to investigate the association of students' grade level with the correlation between math- and language-related motivational beliefs, and thus to contribute to a better understanding of how different sources of self-relevant information might impact students' self-perceptions at different ages. We start with reviewing the literature on the development of self-relevant motivational beliefs and the sources that students use in forming these beliefs across different developmental stages. Then, we present meta-analytic evidence of the associations between students' math- and language-related motivational beliefs. A significant decrease in these associations would be

consistent with the hypothesis that students' use of dimensional comparisons—relative to other sources—increases with age across the school years.

Developmental Changes in the Influences on Self-Relevant Motivational Beliefs

Researchers have studied the ontogeny of children's motivational beliefs, especially their self-perceptions of competence, since the 1970s. In a comprehensive review, Stipek and MacIver (1989) concluded that changes in children's self-perceptions of competence are based not only on age-related changes in children's cognitive abilities, but also on the nature of their educational environments. Input from socializers, especially that from parents and teachers, is one main source that children can use to assess their competence in the absence of absolute standards for judging their own abilities in early childhood. Studies with children from the United States (Wigfield et al., 1997) and Germany (Spinath & Spinath, 2005) have reported a positive relation between parent and teacher ratings of children's competence and students' ability self-concepts from as early as second grade.

Another main source that children start to use by second grade is objective performance feedback. For example, Parsons and Ruble (1977) proposed that one of the first developmental tasks associated with the formation of ability self-concepts is being able to link one's self-concept of ability and expectations for success to cumulative performance information. From a cognitive point of view, drawing these inferences requires that the child be both motivated and cognitively able to integrate performance feedback across time in order to form a stable inference about one's competency and about the probability of success in the future. Parsons and Ruble varied performance feedback to young children of different ages and assessed their expectations for success on the next task. They found that kindergartners usually expected to succeed on the next trial regardless of whether they had just succeeded or failed on a similar task. By second

grade, young children begin to lower their expectations for success linearly following a series of failures. This finding is consistent with the developmental work by Harter (2012), which points to possible cognitive limitations in young children's ability to answer self-reflective questions at earlier ages. Also consistent with this work is empirical evidence demonstrating that children's ability self-concepts become more accurate with age (Davis-Kean et al., 2008; Möller et al., 2020; Wigfield et al., 2006).

Children's formation of perceived competence can also be influenced by social comparisons. Children's social comparison behaviors, such as looking at other children's work or ranking themselves and other children on a given dimension, have been observed as early as kindergarten (Morris & Nemcek, 1982; Pomerantz et al., 1995). While the evidence on when children begin to use social comparisons to evaluate their competency is inconsistent, it is clear that children's ability judgments are affected by normative information in second grade, i.e., around 7-8 years of age (Ruble et al., 1980; Stipek & Tannatt, 1984). For example, Ruble et al. (1980) found that second graders' ratings of their ability on a task were affected not only by their own performance outcome but also by information about other children's performance. This pattern of results suggests that children's ability to integrate performance information and social comparative information in forming their motivational beliefs about their own abilities and preferences increases over time. In addition, contextual changes in educational environments, such as more frequent normative evaluations as children progress through the school system, provide ample opportunities for social comparisons (for an overview, see Cimpian, 2017).

At what point in their educational trajectories children begin to show evidence of using dimensional comparisons has not been extensively studied. The ability to use dimensional comparisons relies on the ability to differentiate competence across different achievement

domains. That is, the process of comparing one's relative performances and enjoyment across subject areas requires individuals to be able to acknowledge that their abilities in different areas can be different or even contradictory. Such differentiation of ability self-concepts and other motivational beliefs such as interests has been found for children across the early elementary school years (Eccles, Wigfield, et al., 1993). More frequent normative evaluations across subjects in higher grades make it easier for students to obtain dimensional comparisons information (Mac Iver, 1987), and at the same time, students increasingly face pressure to specialize and choose among different domains over the school years (Gaspard et al., 2020). Both of these trends suggest an increase in students' use of dimensional comparisons across development. In the next section, we review the theories and studies on dimensional comparisons from a different—non-developmental—perspective.

Past Work on Dimensional Comparisons

Most of the current empirical work on dimensional comparisons comes from the work by Marsh, Möller, and their colleagues. They proposed the internal-external frame of reference model (I/E model) and its newer extension, dimensional comparison theory (DCT) to explain the nearly uncorrelated relation between (adolescent) students' math and verbal self-concepts found in their multiple datasets, despite a strong positive correlation in students' performance across domains (Marsh, 1986; Möller & Marsh, 2013). According to their I/E model and dimensional comparison theory, there are two counterbalancing comparison processes: external (also called social) comparisons and internal (also called dimensional) comparisons. In the I/E model, external comparisons involve comparing one's own performance with relevant peers' performance (e.g., classmates). Because verbal and math abilities are substantially positively correlated, external comparisons should lead to a positive correlation between verbal and math

self-concepts of ability. Internal comparisons involve comparing one's ability in one school subject with one's ability in another school subject. If students conclude that they are relatively better at either math or language arts, this type of internal comparison should lead to a negative correlation between their verbal and math self-concepts because high perceived ability in one domain sets a high standard against which one's ability in alternative domains is being compared. These two comparison processes may jointly result in a nearly uncorrelated relation between students' math and verbal self-concepts of ability. Evidence of weakly positive to negative associations between math and verbal self-concepts was found in several of Marsh's studies with adolescent students (Marsh et al., 2001; Marsh et al., 2009; Marsh et al., 2015).

However, the role that development plays in the I/E model and dimensional comparison theory is unclear. Research is also inconsistent with regard to whether and how comparative processes described in these theories might be influenced by age or grade level. Although the correlation between math and verbal self-concepts is substantial for students in preschool to third grade (Marsh & Ayotte, 2003; Marsh et al., 1999; Marsh et al., 2002), recent studies have reported the correlation flipping from a positive value to a negative one across the K-12 period (Gunderson et al., 2017; Umarji et al., 2018). These findings contradict previous evidence that there may not be a further decline in the correlation beyond Grade 5 (Marsh, 1986, 1989).

Two existing meta-analytic reviews of the relation between students' math and verbal self-concepts have provided mixed results for the estimated school-year effects. Although the developmental process was not their main focus, these two meta-analyses coded year in school as a potential moderator when investigating the relations between students' math and verbal self-concepts. Both meta-analyses were conducted by Möller and colleagues (Möller et al., 2009, 2020). The authors reported somewhat different patterns for the school-year effects on the

relation between students' math and verbal self-concepts. Möller et al. (2009) found that the correlation between math and verbal self-concepts is highest for younger students before Year 7 ($r = .27$) and lowest for students between Years 7 and 9 ($r = .01$), with older students (beyond Year 9) in the middle ($r = .09$). This pattern produced a nonsignificant linear moderation effect for years in school. In contrast, Möller et al. (2020) found a significant linear moderation effect of school year after including more datasets. They divided their sample into two categories and found a significant difference in the correlation estimated within each of the two groups: $r = .23$ (elementary school) versus $r = .09$ (secondary school). Because neither of these studies focused on development specifically, they used quite broad age or grade categories, thus limiting what can be concluded about the developmental changes in students' ability self-concept formation. Furthermore, their focus was limited to analyses of students' ability self-concept, so that we know little about analogous developmental processes concerning other self-relevant motivational beliefs such as interest. Although constructs such as ability self-concept and interest are closely related, they differ in conceptual definitions, in how they are measured, and in their associations with performance. Thus, research is needed to examine whether there might be different patterns of change for other motivational beliefs apart from ability self-concepts.

Influence of Dimensional Comparisons on Other Self-Relevant Motivational Beliefs

We conceptualized academic motivational beliefs based on Eccles and colleagues' Expectancy-Value Theory (Eccles & Wigfield, 2002, recently revised and renamed as the Situated Expectancy-Value Theory, SEVT, Eccles & Wigfield, 2020). The theory has laid out two distinct sets of motivational beliefs: beliefs about how one will do on different tasks or activities (i.e., expectancies) and beliefs about the reasons for doing the activity (i.e., subjective task values). We included these two different sets of motivational beliefs in the meta-analysis, and

further allocate five commonly used constructs in the literature (ability self-concept, self-efficacy, composite self-concept¹, interest, and task values) to the two broad categories of motivational beliefs. Among the five constructs, the first two are conceptually related to expectancy beliefs in SEVT, the last two are related to subjective task values, whereas composite self-concept measures include both expectancy and subjective task value items.

The potential influences of dimensional comparisons on other self-relevant motivational beliefs, beyond students' self-concepts of ability, are not well understood. For example, subjective task values are individuals' beliefs about the value of a given task, including intrinsic value, importance value, utility value, and relative cost (see Eccles & Wigfield, 2020 for a more detailed discussion). Wigfield et al. (2020) argued that the influence of dimensional comparisons on individuals' subjective task values might be weaker than that on corresponding ability self-concepts. They suggested that subjective task values are more complex concepts than ability self-concepts and there are additional sources of information children can use in forming them, compared with those for forming ability self-concepts. Additional sources of information may include cultural norms and ideas about what is appropriate for children to do in a given context, which can shape the value children place on different activities. Indeed, the impact of dimensional comparisons varies across different task value components with the strongest impact found in intrinsic value (Gaspard et al., 2018). Intrinsic value is typically labeled as interest in subjective task value theories so that we use these two terms interchangeably in this paper. The reasons for a strong influence of dimensional comparisons on interest may be that, first, just like

¹ The term *self-concept* has often been used interchangeably with *ability self-concept* in the literature. Based on its definition and corresponding measurement developed by Marsh and colleagues, we believe that self-concept is a composite of ability-related and task value-related motivational beliefs. In this paper, we use the term *ability self-concept* to refer to ability-related self-ratings, and *self-concept* or *composite self-concept* to refer to conceptualizations and assessments of students' self-concept that include both ability-related and task value-related motivational beliefs.

ability self-concepts, children's interests are differentiated across domains during the early elementary school years (Eccles, Wigfield, et al., 1993). Both interests and ability self-concepts may share a similar process of differentiation across domains (Todt, 1990; Todt & Schreiber, 1998). Second, there is also a decline in students' domain-specific interest over the school years that is comparable to the decline in students' ability self-concepts (Scherer & Preckel, 2018). Third, researchers have argued that the development of students' ability self-concepts affects the development of their interests (Marsh et al., 2005). Students tend to show a comparatively stronger interest in those domains for which they have a higher self-concept of ability (Denissen et al., 2007; Köller et al., 1998; Rottinghaus et al., 2003). To date, no meta-analysis has examined potential age or grade level effects on the relation between math and verbal interests or other task value beliefs.

Taken together, there is some evidence for a decline in the correlation between students' math and language ability self-concepts during the early school years, but mixed evidence regarding whether and at what point in students' educational trajectories the correlation might change signs. Moreover, prior work has relied on relatively broad age bins, which limits our understanding of developmental processes. It remains unclear to what extent math and language ability self-concepts become more distinct from each other with age, especially beyond primary school, and whether this developmental pattern can be extended to other self-relevant motivational beliefs. Theoretically, because various other developmental changes (e.g., children's increasing ability to integrate performance information with their self-concepts) are occurring simultaneously, the relative importance of dimensional comparisons versus other sources in forming self-concepts of ability is unclear. The current meta-analysis is conducted to address these research gaps.

The Present Study

The current meta-analysis differs from the previous meta-analyses (Möller et al., 2009, 2020) in three ways. First, the previous meta-analyses used a meta-analytic path analysis to estimate the relations between students' academic achievement and academic self-concept; accordingly, they included studies that reported correlations among students' math and verbal achievement and self-concepts. In our meta-analysis, we included studies that reported zero-order correlations between math and verbal motivational beliefs, which led to a somewhat different set of included studies. Second, the previous meta-analyses used quite broad age or grade categories, whereas we coded the grade level of each study as precisely as possible and excluded studies that only reported correlations for mixed-grades samples. Our data are thus better suited for analyses of developmental processes over time. Third, the previous meta-analyses focused mostly on students' ability self-concept. We expand upon this evidence by exploring whether the developmental pattern of the relations between math and verbal ability self-concepts can be extended to other self-relevant motivational beliefs as well. Therefore, our findings would be able to indicate whether there are any common cognitive and/or contextual influences that might shape a variety of self-relevant motivational constructs. Taken together, while the previous studies aim to test the existence and robustness of the I/E model and dimensional comparison theory, the goal of the current study is to examine potential developmental changes in the associations between math and verbal motivational beliefs more broadly and the extent to which dimensional comparison processes may shape students' self-relevant motivational beliefs at different points in their educational careers.

This meta-analysis addresses two main questions. First, do the relations between math and language motivational beliefs decrease by grade level? We predicted the strength of the

relations between math and language motivational beliefs would decrease with grade level based on both available theory and prior evidence. Theoretically, this meta-analysis is guided by our hypotheses that dimensional comparisons are involved in the formation of motivational beliefs across the childhood and adolescent years and that the extent of the involvement is likely to increase over age. As we mentioned earlier, because of children's social-cognitive development and changes in the school environment, it is possible that students become both more able and more motivated to engage in dimensional comparisons and use dimensional comparisons to form motivational beliefs over the school years. Furthermore, as students develop their identities and may perceive a benefit to specializing in a given academic domain, dimensional comparisons may be a mechanism through which they choose a domain in which to specialize. Besides, evidence from longitudinal studies has suggested dimensional comparison effects on students' ability self-concepts for students beyond fourth grade (Pinxten et al., 2015), but no such effects in grades 1 and 2 (Weidinger et al., 2019). Both meta-analytic studies cited earlier reported larger positive correlations between math and language self-concepts of ability for elementary-level relative to older students.

Our theoretical hypotheses regarding changes in dimensional comparisons can be tested by examining the change of the associations between math and language motivational beliefs over time.² Students use different sources of information to form perceptions of their competence, and these sources are sometimes conflicting, thus making competing predictions

² We chose to focus on math and language specifically because K-12 educators spend the most time on math and language instruction, they are the most frequently assessed domains in national and international exams, and the majority of studies on students' academic motivational beliefs have focused on math and language. In addition, math and language represent contrasting domains. According to the dimensional comparison theory, negative contrast domains occur only if two domains are perceived as dissimilar (such effects do not apply to math and physics, for instance). Accordingly, the hypothesis we are testing likely only applies to contrasting domains such as math and language. For further details of the dimensional comparison theory, see Möller and Marsh (2013).

about the change of the correlation between math and language motivational beliefs over the school years (see Table 1). If students' formation of self-relevant motivational beliefs is based primarily on outside information (e.g., objective test scores), we should see a consistent positive correlation between math and language motivational beliefs across time because students' math and language achievements are consistently positively correlated over age. If students' formation of those beliefs is based mainly on social comparisons, we should also observe a consistent positive correlation because of the same reason. It is only from an increasing reliance on dimensional comparisons over age that we would see a "correlation flip" from a positive value to a neutral or negative one across the childhood and adolescent years.

The second question is how robust the results are when considering a variety of potential moderators. We discuss the potential moderating factors below.

Potential Moderators

Construct. Would the results vary across different motivational constructs? In previous meta-analytic reviews, the term *self-concept* has often been used to represent all results reported in a given study, even when the measures might reflect different constructs. For instance, in their meta-analysis, Möller et al. (2009) found that the correlation between math and verbal self-efficacies ($r = .50$) is larger than those for ability self-concepts ($-.03$) and for composite self-concept ($r = -.03 \sim .22$). The more recent meta-analysis by Möller et al. (2020) combined results from research on students' ability self-concepts and composite self-concept and did not investigate potential differences between these constructs. Thus, we do not know whether the observed change in the correlation between students' math and language motivational beliefs over time is consistent across different constructs.

As we mentioned, the effects of dimensional comparisons on different self-relevant motivational beliefs may vary, as self-relevant motivational beliefs differ in their association with levels of performance. In this meta-analysis, ability self-concept refers to students' beliefs about ability and is based on their evaluations of self-competence in different areas. Self-efficacy refers to students' specific beliefs about their efficacy to do something. Self-concept is defined as a person's perception of self in general or in a specific domain (Shavelson et al., 1976). Interest is similar to intrinsic motivation in our definition and refers to the experience of joy and pleasure in learning for its own sake. Subjective task values have multiple components, including interest, importance value, utility value, and cost. It is possible that ability self-concepts, interests, and self-concepts share a similar developmental pattern because all of them are closely related to actual performance.

On the other hand, although students' domain-specific self-efficacies are also associated with performance, they are goal-referenced evaluations of competence rather than being heavily normative (Bong & Skaalvik, 2003). As a result, both social and dimensional comparison effects have been found to be comparatively weaker for students' self-efficacy ratings than for their self-concepts of ability (Marsh et al., 2019). Accordingly, we examine potential age-related changes in the correlation between students' math and language self-efficacies as an exploratory question and refrain from stating a specific hypothesis. Similarly, we explore analogous effects for students' subjective task values, but refrain from stating specific hypotheses because task values include multiple components (e.g., interest and utility value) and there is a relatively small number of prior studies.

Geographic locations. Countries and districts across the world have different educational systems. Here, we conducted comparative analyses only between German and U.S.

studies due to insufficient data from other countries. In Germany, students typically do not receive school grades until Grade 3 (Spinath & Spinath, 2005), usually attend elementary school in Grades 1-4 and secondary school in Grades 5-12/13, and attend different academic track schools after elementary school, depending on their academic ability and the wishes of their families. In contrast, students in the US typically attend primary school in Grades K-5 or 6, middle school in Grades 6 or 7-8, and high school in Grades 9-12. Previous meta-analyses did not find country-specific differences in the correlation between students' math and verbal self-concept, but it is unknown whether developmental differences in these correlational patterns might nevertheless exist. In countries such as Germany, early academic tracking may imply increased external pressures on students to identify their academic strengths and weaknesses quite early as well as increased use of normative evaluative feedback, thus leading them to make more dimensional comparisons compared with their American counterparts at the same age. Furthermore, academic tracking implies that students are grouped with other students of comparable abilities, which reduces between-person differences in ability and may make within-person differences more salient as a result. Breda and Napp (2019) found that in countries with a higher level of horizontal stratification (e.g., more educational tracks, students being sorted into different education programs at an earlier age), 15-year-old girls showed a larger comparative advantage in reading than boys (i.e., a larger difference between math and reading ability). This supports the idea that in countries with early tracking practices, students may strive to identify their relative strengths earlier (e.g., girls identify reading as their strength) and specialize in their relative strength area more, which may relate to students' engaging in dimensional comparisons earlier. Accordingly, we examined whether German students, who experience academic tracking earlier than their American counterparts, might have comparatively more differentiated self-

related motivational beliefs at a comparatively earlier age. We examine country-specific differences in an exploratory fashion.

Response formats of measurement. Different response formats may influence the results. For example, responses to Agree/Disagree rating scale questions were found to have lower reliability and validity than responses to comparable questions offering Item Specific response options among participants aged 15 and over (Saris et al., 2010). We explored the robustness of the grade-level effects under different measure response-formats as an open research question.

Type of Index for Calculating r . Marsh (1989, 1990) found that correlations between factor scores were consistently lower than correlations between raw scale scores. A contrasting pattern has been found in some other studies (e.g., Sewasew & Schroeders, 2020). We tested whether the correlational pattern over time was affected by the use of latent versus observed correlation coefficients.

Types of data. Would data from cross-sectional designs or longitudinal designs produce a different pattern of results? We conduct exploratory analyses to answer this question, but we did not expect the grade-level effects to be influenced substantially by this factor.

Method

Literature Search

Articles for this meta-analysis were identified in two ways. First, a computer search of the PsycINFO, ERIC, and PsycARTICLES databases for literature was conducted. We used the earliest possible start date until March 2021. Titles, abstracts, and keywords were searched for the following terms: math* AND (reading OR language OR English OR German OR verbal) And (interest OR “self concept” OR “self efficacy” OR “task value” OR “self perceived” OR

“self perception” OR motivation). The asterisks can help include different forms of search terms (e.g., math* includes math and mathematics). Second, we searched in previous relevant reviews and also contacted researchers to request correlation tables not provided in their reported studies. The initial search yielded 903 articles. We then reviewed all studies by titles and abstracts. After excluding 248 duplicate articles and 465 irrelevant articles, the remaining 190 articles were closely reviewed using the specific criteria described below (see Figure 1 for the flow diagram of the search and inclusion criteria for studies included in the present review).

First, eligible studies had to include at least one self-reported measure assessing students’ math motivational beliefs and a corresponding measure assessing language or reading-related motivational beliefs. Measures of math motivational beliefs include those measuring motivational beliefs or attitudes in the math domain such as math interest, ability self-concept, and importance value. Measures of language or reading motivational beliefs include those measuring motivational beliefs or attitudes in the language or reading domain (see Table 2 for definitions of different motivational beliefs and corresponding examples). We decided to exclude studies in which the language domain was not the participants’ native language or in which the math domain was combined with other domains such as science. Second, eligible studies had to report at least one zero-order correlation (r) between any measure of math motivational beliefs and a corresponding measure of language or reading motivational beliefs. Third, studies had to report the grade level of the sample.³ Since we are interested in the developmental pattern of the

³ We decided to rely on the grade level of a sample instead of the mean age because this allowed us to narrow the sample to a specific age group. For instance, if a sample of a study includes children aged from 9 to 16 years old and reported a mean age, including the correlation for this sample would aggregate within- and across-grade variation, when our research questions pertain to how within-grade covariation varies across grades. By focusing on students’ grade level and excluding studies that only reported correlations for mixed-grades samples, we can obtain a correlation for students from a specific age group because students of similar ages tend to attend the same grade level within a given context. In the current meta-analysis, however, the correlation between age and grade level is nearly perfect ($r = .99$).

strength of the relations between motivational beliefs in math and language, we excluded studies that only reported correlations for mixed-grades samples. But if a sample of a study included participants from two consecutive grades, the study was included.

We included publications that have used the same or overlapping datasets in our final analyses because these papers often report different sample sizes and correlation coefficients. We then accounted for sample-specific dependencies in data analysis, as described in the Analytic Strategies section.

Coding Procedure

Variables coded include the following: study, dataset, year of publication, mean age of participants, grade level of participants, sample size, percentage of female students, location of the sample, construct of the measured motivational beliefs, response format of the measurements, type of data, correlation coefficient, and whether the reported correlation was based on latent or observed scores. We included some of these codes as moderators.

Grade Level. Grade level or years in school was defined as a continuous variable. The specific time point of data collection within the same grade level (e.g., at the beginning vs. at the end of a given school year) was also coded and taken into account in the analyses (for coding rules, see Table S1). If a study sample included participants from two consecutive grades, we used the mean grade level (e.g., sample with both 7th and 8th graders was coded as 7.5).

Construct. The constructs used in each study were coded based on the items that were used to assess them. Then they were assigned to the following groups: ability self-concept, self-concept, self-efficacy, interest, and task values. Task values were coded separately from interest because several studies included items on importance value and utility value in their measurement, in addition to items assessing interest. In the literature, ability self-concept, self-

concept, and self-efficacy are often used interchangeably, and high correlations of these constructs have been obtained in empirical research, although they are conceptually distinct (Bong & Skaalvik, 2003; Marsh et al., 2019). Thus, studies of these constructs are sometimes vulnerable to the jingle and jangle fallacies. The jingle fallacy is when scales with the same name are supposed to measure the same construct but actually measure different constructs. The jangle fallacy is when scales with different names are supposed to measure different constructs but actually measure the same construct. In an attempt to avoid the jingle and jangle fallacies, we checked the measurement items in each study to assign the most appropriate code for the assessed construct, based on our definitions. We summarize the key distinctions between different constructs in Table 2.

Geographic Location. We coded where the sample in each study was from. Then we assigned them to the following groups: Asia, Australia, Canada, Europe (apart from Germany), Germany, or United States.

Response Format. We coded the response format of the measurements as a Likert scale associated with a statement, a Likert scale with item-specific answer options, or other. A Likert scale format associated with a statement would ask participants to respond to statements with answer options ranging from, e.g., *strongly disagree* to *strongly agree*, *completely false* to *completely true*, *always no* to *always yes*, and *does not apply to me at all* to *applies to me completely*. A rating scale with an item-specific format would ask participants to respond to a question by choosing a specific answer for the item. For example, “How good are you at math?” with response options ranging from 1 (*very good*) to 5 (*very bad*). The residual category “Other format” includes measurements that do not fit into the above categories.

Type of Index for Calculating r . We coded whether the correlation was calculated and reported based on latent or observed scores. Here, observed scores (also named as manifest scores) refer to the mean or sum score of all items.

Type of Data. We coded whether the data were cross-sectional or longitudinal. If a study only reported one wave of data from a longitudinal study, it was coded as cross-sectional.

All study characteristics and moderators were coded independently by the first author and two trained research assistants. The inter-rater reliability was .80~.99 for all variables of interest. In cases of discrepancies in coding, disagreements were resolved by further examination of the studies and discussion until full agreement was achieved.

Analytic Strategies

The effect size index used for all outcome measures is Pearson's r , which captures the correlation between math and language motivational beliefs. We selected 142 independent studies for this analysis, but many of them contained several different constructs and collected data at more than one measurement point. Hence, these studies contained more than one effect size from the same participants. This led to a complex data structure with 426 partly dependent effect sizes within 142 independent studies. To control for the dependence of effect sizes within studies without the loss of power and information, we used the robust variance estimation (RVE) method (Hedges et al., 2010; Tipton, 2013). This analysis handles clustered data (i.e., effect sizes nested within samples) by correcting the estimated standard errors so that correlations between different effect sizes from the same sample are taken into account. To conduct the RVE meta-analysis, we followed the guidance of Tanner-Smith et al. (2016) and used the *robumeta* package in R (Fisher & Tipton, 2016). The robust variance estimation involves a working model that assumes a common correlation (ρ) between effect sizes within a cluster for calculating the

between-study sampling variance estimate τ^2 . In all analyses, we estimated τ^2 with $\rho = .80$.

Sensitivity analyses showed that the results were robust across different estimates of ρ .

We converted correlation coefficients to Fisher's Z scale, and all analyses were performed using transformed values. The results, such as the summary effect and its confidence interval, were then converted back to correlation coefficients for presentation. We first estimated the overall weighted mean correlation between math and language motivational beliefs. Then, all moderators were entered into the model simultaneously to test whether grade level moderated the relations between math and language motivational beliefs after controlling for other moderators. In addition, to test whether the effect of grade level is robust, we examined it based on the correlations between math and language motivational beliefs for each subgroup of moderators.

Publication Bias

Publication bias is the problem that the decision to publish a study is influenced by its results (i.e., the studies are more likely to get published when the results are significant). Most of the studies we considered did not aim to investigate the correlation between motivational beliefs in two different domains but rather relations of motivational variables with other variables (e.g., achievement in the same domain). As a result, in most cases, the likelihood of publishing an article should not depend on a particular or significant direction of the correlation. In fact, many very small correlations, positive and negative, have been published, inconsistent with the idea that there is a strong preference for publishing only significant findings. Additionally, it has been found that correlational meta-analyses are less susceptible to bias due to the publication process (Chow & Ekholm, 2018). For all these reasons, we focused our search strategy on published studies. To account for publication bias in these studies, we conducted a funnel plot analysis by using the *metafor* package in R (Viechtbauer, 2010) and carried out Egger sandwich tests for

funnel plot asymmetry with dependent effects (Rodgers & Pustejovsky, 2020). We did not find significant publication bias based on the Egger sandwich tests for the correlations between math and language motivational beliefs of each construct (for the funnel plots, see Figures S1-S5 in the Supplemental Materials). This result and the aforementioned reasons for focusing on published studies suggest that our decision to include only published studies did not lower the quality of the meta-analysis.

Results

Description of Studies

Based on our inclusion criteria, 103 studies involving 142 independent samples, 210,954 participants, and 426 correlations between math and language motivational beliefs were included in the final analyses (for all study characteristics, see Table S10 in the Supplemental Materials). The 103 articles were published between 1983 and 2021, with the median in 2013. Sample sizes ranged from 49 to 39,192, with a mean of 1,486 and a median of 384. With respect to the geographic location, 20% of the samples ($N = 42,401$) were from the United States, 9% ($N = 18,013$) from Australia, 4% ($N = 9,469$) from Asia, 1% from Canada, 46% ($N = 96,111$) from Germany, and the remaining 20% ($N = 42,097$) from other European countries. The mean portion of female participants was 51% (range = 0 to 100%, $SD = 15\%$, Median = 51%). The grade level ranged from 1 to 13 (Mean = 6.5, Median = 6.6). For the distribution of the number of effect sizes across grades, see Figure S6 in the Supplemental Materials. Mean age ranged from 6 to 19.8 (Mean = 12.1, Median = 12.1). The median number of effect sizes per study was 2, with a range of [1, 60]. The median number of effect sizes per sample was also 2, with a range of [1, 26] (for the distributions, see Figures S7 and S8). The number of effect sizes for each subgroup is presented in Table 3.

Relation between Math and Language Motivational Beliefs

The overall magnitude of the relation between students' math and language motivational beliefs was $r = .16$, 95% CI [.12, .20]. As shown in Table 3, the average correlations in different subgroups are between .05 and .44, indicating a moderate positive relation. We report the correlations between math and language motivational beliefs for different constructs in the Supplemental Materials (see Tables S2-S6). The overall magnitude of the relation between math and language ability self-concepts was $r = .13$, 95% CI [.08, .18]. The average effect size was $r = .24$, 95% CI [.17, .30] for math and language interest, $r = .15$, 95% CI [.07, .23] for math and language self-concepts, and $r = .19$, 95% CI [.07, .30] for math and language task values. The overall magnitude of the relation between math and language self-efficacies was $r = .44$, 95% CI [.33, .53].

Moderation Effects of Grade Level

Figure 2 shows a scatterplot of all 426 effect sizes and illustrates changes in the correlations between math and language motivational beliefs over time. As shown in Table 4, grade level emerged as a significant moderator, controlling for the predictive effects of other moderators ($b = -.06$, 95% CI [-.06, -.05]). When other moderators were not included as control variables, the moderation effect of grade level on the math-verbal correlations was $b = -.05$, 95% CI [-.06, -.04] (see Table 7, also see the best-fitting line and its confidence band in Figure 2). The relation between math and language motivational beliefs decreased significantly as the students' grade level increased. On average, every one unit (i.e., a year) increase in grade level is associated with .05 of a unit decrease in the correlation r between math and language motivational beliefs. We also binned the available grade-level data into different groups to illustrate this downward trend (see Table S7). The correlations over time decrease from $r = .32$,

95% CI [.26, .37] in Grades 1-4, to $r = .18$, 95% CI [.12, .23] in Grades 5-8, and $r = -.01$, 95% CI [-.07, .04] in Grades 9-12/13. Based on the confidence band in Figure 2, on average, there is a significant positive association between math and language motivational beliefs through Grade 9 and no significant association around Grade 10; the association significantly reverses (from positive to negative) by Grade 12. Taken together, there is a “correlation flip” during the adolescent years.

We present the moderation effects of grade level for different types of study designs in the Supplemental Materials (see Table S8). The following three types of study designs were included in these analyses: First, there are longitudinal studies, in which the same group of students is followed across different grade levels. Second, there are cross-sectional studies, in which data from several cohorts are included and reported in the same article. Although these cross-sectional studies do not follow the same sample over time, the time of measurement, the researchers conducting the study, the country, the measurement instruments, and several other possible confounding factors are typically held constant across grade levels. Finally, there are independent cross-sectional samples that differ in many other characteristics, in addition to grade level, and that are reported in different articles. Our results show that the moderation effects of grade level for these study designs are similar in magnitude and statistically significant ($bs = -.04, -.05, -.05$, respectively; $ps < .001$). In addition, we estimated the association between students' grade level and the resulting effect size after centering the grade-level predictor within each study from the same article (for cross-sectional studies) or within each sample (for longitudinal studies). The pattern of decline in correlations over the grade level is robust, even when we use centered data ($bs = -.08$ and $-.04$, respectively; $ps = .004$ and $.002$).

Moderation Effects of Grade Level in Subgroups

We examined whether grade level moderated the relations between math and language motivational beliefs for different constructs. Tables 5 and 6 show that the similar effects of grade level on the observed math-verbal correlations were found for both ability self-concepts and interests after controlling for other moderators (Self-concept of ability: $b = -.06$, 95% CI $[-.07, -.04]$; Interest: $b = -.04$, 95% CI $[-.07, -.02]$). For the remaining constructs (composite self-concepts, self-efficacies, and task values), there were not enough data to run the moderation analysis, controlling for other moderators. However, when other moderators were not included as control variables, the moderation effects of grade level on the math-verbal correlations for these constructs were $b = -.04$, 95% CI $[-.05, -.02]$ for self-concept, $b = -.03$, 95% CI $[-.10, .03]$ for self-efficacy, and $b = -.05$, 95% CI $[-.09, .00]$ for task values (seen Table 7). Figures 3-7 present scatterplots for different constructs to illustrate these associations with students' grade levels.

We also ran a series of moderation analyses to test whether other moderators might affect the predictive effects of grade level on the correlations between math and language motivational beliefs (see Table 7). The results showed that the moderation effects of grade level were robust for a variety of subgroups. The moderation effects of grade level were not significant in studies using self-efficacy, samples from Europe (except Germany), and samples from studies using nontypical response formats in their measurements (e.g., binary responses).

Other Moderators of the Relation between Math and Language Motivational Beliefs

We found that the type of constructs measured was a significant moderator in the relations between math and language motivational beliefs (see Table 4). Specifically, studies focusing on students' self-efficacy and task values reported higher correlations compared with those focusing on students' ability self-concepts ($b = .39$, 95% CI $[.27, .50]$; $b = .19$, 95% CI

[.07, .32], respectively). Samples from Germany reported lower correlations compared with samples from the United States ($b = -.11$, 95% CI [-.22, -.01]). Samples from studies using nontypical response formats in their measurements reported higher correlations compared with samples using Likert-type-ratings of specific statements ($b = .14$, 95% CI [.01, .27]). Studies reporting results based on latent scores had lower correlations compared with studies using observed scores ($b = -.07$, 95% CI [-.13, -.01]).

Discussion

We investigated whether the correlations between students' math and language motivational beliefs in school-aged children and adolescents vary by grade level. Our meta-analysis revealed a significant decline in the relations between students' math and language motivational beliefs over time. This finding holds for both ability self-concepts and interests. Our results also indicated that the geographic locations of the samples, the response formats of the measurement, the type of correlation (manifest vs. latent), and the type of data (cross-sectional vs. longitudinal) did not influence our estimate of a general decline. These findings thus provide meta-analytic evidence to support the idea that math and language motivational beliefs become more differentiated over time. It suggests that dimensional comparisons play a comparatively bigger role among other sources of information in the formation of students' motivational beliefs across the school years.

Change in the Correlations between Math and Language Motivational Beliefs over Time

Our findings are in line with the results reported by Möller et al. (2020), and partially consistent with Möller et al. (2009)'s results. The relations between math and language ability self-concepts decrease over time during the school years (see Figure 3 and Table 5). We found a similar pattern for students' math-verbal interests and self-concepts (see Figures 4 and 5, and

Tables 6 and 7). Compared with the two previous meta-analytic studies by Möller and colleagues, our study was specifically designed to examine age-related changes in ability self-concept formation and other self-relevant motivational beliefs and therefore used comparatively more precise grade categories and a broader range of motivational constructs when selecting and coding eligible studies. Furthermore, we tested the robustness of our findings against different methodological factors (e.g., response formats of measurements). In particular, we found that the meta-analytic average correlation became significantly negative in Grade 12 (see Figure 2), a pattern that has not been reported in the previous meta-analytic studies.

The observed decline in the association between students' math and verbal self-concepts of ability is consistent with our hypothesis that the relative importance of dimensional comparisons, relative to other sources of ability self-concept formation, increases over time. Previous experiments, cross-sectional studies, and longitudinal studies have indicated that dimensional comparisons seem to occur later than social comparisons during child development (Ehm et al., 2014; Lohbeck & Möller, 2017; Ruble et al., 1980; Schmidt et al., 2017). Similarly, our analyses suggest that the correlations between students' math and language ability self-concepts are positive for early graders, but as students grow older, the direction of the meta-analytic average correlation switches from positive to negative (see the confidence band in Figure 2). This pattern of results indicates that for high schoolers, the effects of dimensional comparisons on students' ability self-concepts likely outweigh other sources such as social comparisons and objective performance which support a positive association between students' math and verbal self-concepts.

The relatively small number of studies focusing on the associations between students' math and verbal self-efficacy, as well as math and verbal task values, calls for caution in the

interpretation of our findings regarding the developmental pattern of these associations over the school years. Nevertheless, our findings are consistent with previous literature (Möller et al., 2009): The correlations between math and language self-efficacies tend to be larger than those between math and language ability self-concepts (see Tables 3 and 4). As we discuss in the introduction, students' ability self-concepts rely heavily on normative references and evaluative cross-domain comparisons of students' relative strengths and weaknesses. In contrast, students' judgments of self-efficacy rely on goal-referenced self-evaluations and are thus comparatively better aligned with students' actual achievements, which tend to be positively correlated across domains and over time (Bong & Skaalvik, 2003; Marsh et al., 2019). Thus, our finding that all correlations for students' self-efficacies are positive in our meta-analysis is plausible and points to different developmental patterns across constructs. It is also important to note that all of the available data for students' self-efficacies in our meta-analysis are from children in or beyond Grade 5 (see Figure 6). As a result, we do not know how our findings on self-efficacy would generalize to younger children.

Possible Reasons for the Observed Increase in Students' Use of Dimensional Comparisons Over Time

Our results suggest that, as students become older, they are increasingly more likely to use dimensional comparisons to evaluate their abilities. As shown in Table 1, there are several possible reasons for this increase in students' use of dimensional comparisons, which is likely to manifest itself in a decreasing correlation between students' math and verbal self-evaluations. First, as children grow older, they become better at differentiating their domain-specific ability self-concepts. Evidence suggests that up until the ages of 8 to 10 children have difficulty acknowledging that their performances across domains can be different or even contradictory

(e.g., Harter, 2012). In comparison, this task would not be cognitively challenging for adolescents.

Second, the use of normative evaluations becomes more frequent across subjects as students move to higher grades (e.g., Mac Iver, 1987). Thus, along with the cognitive-developmental advances mentioned above, the increasing availability of normative evaluations across subjects may further facilitate students' engagement in dimensional comparisons and their use of dimensional-comparative information in forming their ability self-concepts and potentially other self-relevant motivational beliefs such as interests.

Third, in later school years, students are provided with more opportunities to make choices and are expected to specialize in certain domains. Wolff et al. (2018) found that dimensional comparisons are driven primarily by such self-differentiation motivations, that is, by students' motivation to identify their strengths and weaknesses across various domains. Dimensional comparisons can support students' decision-making for important choices such as which course to enroll in or which college major and career path to pursue. Furthermore, external pressures to specialize can differ across educational contexts, for instance, as a consequence of the onset of academic tracking. In this study, we performed comparative analyses for students in US versus German samples, because students in Germany are subject to earlier academic tracking (typically, after Grade 4) and may thus face greater pressures to specialize and identify their academic strengths and weaknesses. Although we found no significant differences between these two countries, students in Germany did experience a slightly larger decline in the correlation between their math and verbal ability self-concepts compared with those in the U.S. (see Table S7). Due to the substantial variability within each country and other differences in contexts, it is premature to conclude whether the timing of academic tracking might influence

students' self-evaluations across domains. Nevertheless, we believe that the aforementioned trend found in our data merits further investigation and that future developmental analyses should take into account potential differences in academic tracking across educational contexts.

Finally, as students' use of social comparisons increases over time, so does the negative impact of such comparisons on students' self-esteem (Harter, 2012). Accordingly, students may use dimensional comparisons as a means to protect and enhance their self-images by shifting their attention to domains in which they perceive comparative strengths. In their diary studies, Möller and Husemann (2006) found that students use dimensional comparisons as a means to improve their mood. In sum, older students might be more motivated to make dimensional comparisons for the sake of self-differentiation, self-protection, or both.

The Potential Consequences of Students' Increasing Use of Dimensional Comparisons

On the one hand, students may use dimensional comparisons to specialize in a given domain and to protect their positive self-image by focusing on domains of relative strength. On the other hand, reliance on dimensional comparisons might be harmful in some cases. For instance, if a student with strong math performance and normal language performance is in a class with only very high math achievers, a promising mathematics student might identify as a "reading person" because they feel relatively stronger in reading. This dynamic has been proposed to account for some of the gender gap in science, technology, engineering, and mathematics (STEM) representation. In particular, it has been argued that girls' comparative advantage in reading explains a significant portion of the gender gap in students' probability to pursue math-related fields and careers (Breda & Napp, 2019; Cimpian et al., 2020; Wang et al., 2013). Thus, dimensional comparisons may lead girls to feel less confident or interested in math

because, on average, girls tend to have similar math abilities as boys but often outperform boys in verbal domains.

Furthermore, dimensional comparisons might be related to the average declines in math and language ability self-concepts and interests, as documented in prior research (Gaspard et al., 2020; Orth et al., 2021; Scherrer & Preckel, 2019; Schiefele, 2009). That is, individual students' specialization in one particular domain implies an average group-level decline in students' motivational beliefs, as students maintain or intensify their involvement in one domain but disengage from other domains at the same time (Gaspard et al., 2020). Younger students tend to perceive their competence in different academic domains as relatively high, whereas older students tend to rate themselves as more competent in some domains but less competent in others.⁴

If the increasing use of dimensional comparisons over age and the process of differentiation are underlying causes of the decline in students' motivation over time and of persistent gender gaps in students' STEM career choices, it is important to ask whether dimensional comparisons should be supported or discouraged. If the goal is to encourage students to keep their academic options open for as long as possible, then it would be sensible to highlight the similarities between math and language arts and to convey the message that one can (and typically does) do well in both domains. But if the goal is to encourage students to specialize in a particular domain so that they can develop their unique strengths, then dimensional comparisons can be supported at the expense of students' motivational decline in

⁴ It is worth noting that the results of the current meta-analysis do not imply that individuals rate themselves higher in reading self-concept than in math self-concept or vice versa. A supplementary analysis using an individual dataset in the Supplemental Materials shows that older students are generally more likely to rate themselves as a language person than a math person (see Table S9). The pattern is consistent with previous literature (Gaspard et al., 2020). Still, the generalizability of such a pattern requires future research.

some domains. A broad perspective that considers the potential benefits and costs of using dimensional comparisons for both individuals and society would be useful for understanding when such comparisons should be encouraged or discouraged.

Limitations

We note several limitations of our study. First, the evidence our analyses provide for the changes in students' use of dimensional comparisons is indirect. We interpret the observed changes in the correlations between students' math and language motivational beliefs as the result of changes in the relative strength of dimensional comparisons among all sources of influence. This interpretation relies on the assumption that dimensional comparisons should result in a negative correlation between students' math and verbal self-concepts, which we derived from Marsh's I/E model (see Marsh & Yeung, 2001). Although the meta-analytic approach we use does not allow us to directly assess whether students engage in dimensional comparisons, the assumption we rely on has been supported by studies that explicitly asked students to make dimensional comparisons (Dickhäuser, 2005; Müller-Kalthoff et al., 2017; Wolff, Helm, Zimmermann et al., 2018; Wolff, 2020).

Second, we rely on correlational data, which prevents us from drawing causal inferences. That is, the increases in dimensional comparisons do not necessarily mean that there is a stronger negative causal effect from reading (or math) self-concept or achievement on subsequent math (or reading) self-concept for older students. It is unknown whether there is any psychological process shaping the relations between students' self-concepts across domains without the influence of students' achievements. In other words, complex dynamics may exist in the process of self-concept formation. Nevertheless, we caution that there may be unintended side effects of motivational interventions that target only a single academic domain (e.g., math motivation) for

adolescent students' motivations in alternative domains (e.g., verbal motivation) so that researchers should be cautious about whether and when to promote motivation in a single subject. Indeed, Gaspard et al. (2016) report negative effects of a math task-value intervention on students' German task values among 9th graders, but their paper is the only study on this topic to date. More research is therefore needed.

Third, our analyses of developmental changes in students' use of dimensional comparisons are limited to two (dissimilar) domains: math and language arts. Due to a scarcity of available research, we were unable to examine if the correlations among students' motivational beliefs may change in other domains as well (e.g., physics or history) over the school years. More research on the development of students' motivational beliefs across different school subjects and age groups is needed to test the generalizability of our findings to other domains.

Fourth, we excluded the studies that either did not specify students' grade level or included mixed grade levels. For example, studies using data from the Program of International Student Assessment (PISA) focus on 15-year-old students who attend grades 7 to 12 in different countries and do not report results separately by grade level. Because of our specific focus on development, we were unable to include this research in our analyses. Previous analyses of the PISA data suggest that the average correlation between students' math and language arts self-concepts for 15-year-olds is .06 (for further details, see Marsh & Hau, 2004).

Fifth, sample size constraints prevented us from exploring the effects of grade level on the math-verbal correlations for some constructs within subgroups (e.g., specific geographic locations), and some of the moderation analyses we conducted may have been underpowered. In particular, we did not have a sufficient number of studies measuring self-efficacy beliefs or task values to test whether the developmental pattern of the observed correlations is robust after

controlling for other potential moderators. We were also unable to examine whether there are any gender differences in the developmental pattern because no existing studies have reported results on this question and the variability of gender ratios in the data is small. Future longitudinal studies might reveal whether girls and boys show developmental differences in the use of dimensional comparisons over time.

Lastly, while we do not find evidence for moderation of the general decline across geographic locations (see Table 7), variation across cultural contexts is likely to exist and may provide useful insights into the underlying developmental processes of the decline. It should be noted that, although our meta-analysis included estimates from samples in 16 different countries and regions, much of the world was not represented. Further, we decided to limit our data to studies published in English, which may have limited the variability in potentially important contextual moderators. Longitudinal extensions of worldwide cross-sectional studies such as Program of International Student Assessment might be the best way to address these issues.

Conclusion

In summary, this meta-analysis revealed a significant decline in the correlations between students' math and language self-relevant motivational beliefs over the school years. The results did not differ by the geographic locations of the samples, the response formats of the measurement, the type of correlation (manifest vs. latent), or the type of data (cross-sectional vs. longitudinal). In addition, this finding was generalizable across several related constructs, including students' ability self-concepts, interests, composite measures of ability-self concept and interest, and task values. The pattern for self-efficacy was similar in magnitude, but imprecisely estimated and not statistically significant. Our results are consistent with our hypothesis that, as students grow older, dimensional comparisons begin to outweigh other

sources such as social comparisons and objective performance in the formation of students' ability self-concept, which results in a decrease in and sometimes a switch of the direction of the correlations between students' math and language ability self-concepts and other related motivational beliefs.

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Table 1

Different Predictions of the Time-Related Change in the Correlations Between Math and Language Motivational Beliefs Based on Different Processes in the Formation of These Beliefs

Contributing process/source	Time-related changes that may influence the contributing process	Corresponding empirical evidence or theoretical argument	Predicted contribution to the direction of r
Objective information of performance	Increase in the cognitive ability to calibrate performance information with their self-concepts.	Students' ability self-concepts become increasingly aligned with their actual performance throughout the school years (Davis-Kean et al., 2008).	Positive
	Increase in the amount of normative, comparative performance feedback.	There are more public postings of grades in later school years (Eccles & Roeser, 2011).	
Social comparisons	Increase in the cognitive ability to engage in social comparisons and to use social comparative information in evaluating one's abilities.	Older children are more skilled than younger children at obtaining and interpreting social comparative information (Stipek & Mac Iver, 1989).	Positive
	Increase in the salience of normative evaluative information and the emphasis on social comparisons and competition in educational contexts.	Middle schoolers reported greater emphasis on competence evaluation and greater knowledge of peers' performance than the previous year when they were in elementary school (Harter et al., 1992).	
Dimensional comparisons	Increase in the cognitive ability to engage in cross-domain comparisons and to use cross-domain comparative information in evaluating one's abilities.	Children have difficulty acknowledging that their abilities in different domains can be different or even contradictory until ages 8 to 10 (Harter, 2012).	Negative
	Increase in the salience of normative evaluation information across different subjects.	The more frequently teachers assign grades on classwork, the more students rely on across-domain comparisons to infer ability (Mac Iver, 1987).	
	Increase in the need/pressure to specialize given by the educational environments (e.g., schools encouraging specialization as students get older).	Students' desire and need to become aware of their strengths and weaknesses may trigger dimensional comparison processes (Wolff, Helm, & Möller, 2018).	
	Increase in the need and the cognitive ability to engage in self-protection and self-enhancement because of the negative impact of social comparisons on students' self-esteem.	Students use dimensional comparisons as a means to improve their mood (Möller & Husemann, 2006).	

Note. We decided to focus on the three contributing sources here because they have been discussed in the internal/external frames of reference model and related literature. A few additional sources/processes can influence the formation of students' ability self-concepts, including temporal comparisons (i.e., comparing one's current performance to previous performances) and input from important socializers (e.g., parents and teachers). We did not include these additional factors in our review because their impact on childrens' self-evaluations is likely to begin in early

childhood (Harter, 2012; Stipek & Mac Iver, 1989) and is not likely to affect the correlations between students' math and language motivational beliefs over time. We also considered alternative explanations for the diminishing correlation between math and language self-evaluations over time. For instance, the content taught in academic subjects such as math and language arts may become increasingly dissimilar over time, which would result in a decreasing correlation from primary school to high school. However, such an explanation would imply a corresponding decline in the correlation between math and language achievements over time, which is not the case. Thus, the change in subject-content similarity is insufficient to explain the differentiation between math and language self-evaluations. Lastly, the predictions in the table are for students beyond second grade. Students younger than that are likely to show inaccurate and overly positive self-evaluations because of cognitive limitations that manifest as all-or-none thinking at this stage (for a review, see Harter, 2012). This could result in either a strong positive or a zero correlation between their ability self-evaluations in math and verbal domains. In-depth coverage of such factors is beyond the scope of the present article.

Table 2

Description of Constructs for Motivational Beliefs in Academic Domains

Types of construct	Definition or coding criterion	Example items
Ability self-concept	Perceived competence of self in a domain; expectancy for future performance in a domain.	“I have always done well in __ (subject)”; “How good in __ (subject) are you?” Competence self-concept in Marsh's Self Description Questionnaire.
Interest	Enjoyment; intrinsic value.	“I am interested in __ (subject)”; “How much do you like doing __ (subject)?” Affect self-concept in Marsh's Self Description Questionnaire.
Self-concept	Perception of self in a domain, comprising facets of both ability-self concept and interest.	Scales including items for both ability self-concept and interest mentioned above. Examples include the long versions of Marsh's Self Description Questionnaire (I-III).
Self-efficacy	Confidence in doing a specific task or activity.	“I am confident in solving the problem correctly”; “I'm certain I can figure out how to do the most difficult class work in __ (subject)”
Task values	Including intrinsic value, importance value, and utility value.	“__ (subject) is important for me personally”; “How useful is what you learn in __ (subject)?” “How much do you like doing __ (subject)?”

Note. The difference between ability self-concept and self-concept is that the latter covers both ability-self concept and interest. The difference between interest and task values is that the latter covers interest, importance value and utility value. If a measurement only includes items on interest, we code it as interest. If a measurement includes items on both interest and importance value, utility value, we code it as task value. If a measurement only includes items on importance value, utility value, we code it as task value too.

Table 3

Correlations Between Math and Language Motivational Beliefs

	<i>k</i>	<i>r</i>	95% CI of <i>r</i>	τ^2
Overall	426	.16	[.12, .20]	.04
Construct				
Ability self-concept	261	.13	[.08, .18]	.04
Interest	71	.24	[.17, .30]	.02
Self-concept	48	.15	[.07, .23]	.04
Self-efficacy	16	.44	[.33, .53]	.02
Task values	30	.19	[.07, .30]	.03
Geographic location				
Asia	27	.05	[-.13, .23]	.07
Australia	45	.22	[.13, .30]	.04
Canada	32	.25	[.07, .43]	.08
Europe (except Germany)	61	.17	[.06, .26]	.03
Germany	178	.12	[.07, .18]	.04
United States	83	.20	[.09, .30]	.02
Response format				
Likert statement	287	.14	[.09, .19]	.04
Likert item-specific	116	.18	[.11, .24]	.07
Others	23	.43	[.27, .56]	.07
Index for calculating <i>r</i>				
Latent score	197	.16	[.11, .22]	.05
Observed score	229	.15	[.09, .20]	.03
Types of data				
Cross-sectional	250	.16	[.11, .21]	.05
Longitudinal	176	.14	[.08, .20]	.02

Note. *k* = number of effect sizes, CI = confidence interval, τ^2 = between-study sampling variance.

Table 4

Moderators of the Correlations Between Math and Language Motivational Beliefs

Moderator	<i>b</i>	<i>SE</i>	<i>t</i>	95% CI	<i>p</i> value
Grade level	-.06	.005	-11.86	[-.06, -.05]	< .001
Construct (reference group: ability self-concept)					
Interest	.02	.032	0.55	[-.05, .08]	.584
Self-concept	-.02	.059	-0.30	[-.14, .10]	.764
Self-efficacy	.39	.052	7.38	[.27, .50]	< .001
Task values	.19	.058	3.33	[.07, .32]	.003
Geographic location (reference group: United States)					
Asia	-.07	.079	-0.93	[-.23, .09]	.361
Australia	-.07	.079	-0.88	[-.23, .09]	.383
Canada	-.01	.082	-0.17	[-.18, .16]	.869
Europe (except Germany)	-.03	.064	-0.49	[-.16, .10]	.629
Germany	-.11	.050	-2.30	[-.22, -.01]	.030
Response format (reference group: likert statement)					
Likert item-specific	.00	.046	-0.04	[-.09, .09]	.971
Others	.14	.060	2.31	[.01, .27]	.040
Index for calculating <i>r</i> (reference group: latent score)					
Observed score	-.07	.031	-2.36	[-.13, -.01]	.021
Types of data (reference group: cross-sectional)					
Longitudinal	-.05	.028	-1.86	[-.11, .00]	.070

Note. *SE* = standard error, *CI* = confidence interval. All moderators were entered in one model.

There are 426 correlations and 142 independent samples. Between-study sampling variance (τ^2) is .02.

Table 5

Moderators of the Correlations Between Math and Language Ability Self-Concepts

Moderator	<i>b</i>	<i>SE</i>	<i>t</i>	95% CI	<i>p</i> value
Grade level	-.06	.006	-9.49	[-.07, -.04]	< .001
Geographic location (reference group: United States)					
Asia	-.11	.094	-1.15	[-.30, .09]	.265
Australia	.16	.083	1.87	[-.02, .33]	.074
Canada	.15	.106	1.40	[-.12, .42]	.220
Europe (except Germany)	.00	.063	0.03	[-.13, .13]	.975
Germany	-.04	.061	-0.65	[-.17, .09]	.525
Response format (reference group: likert statement)					
Likert item-specific	.02	.056	0.37	[-.10, .14]	.719
Others	.04	.100	0.37	[-.22, .29]	.729
Index for calculating <i>r</i> (reference group: latent score)					
Observed score	-.06	.036	-1.60	[-.13, .01]	.115
Types of data (reference group: cross-sectional)					
Longitudinal	-.04	.029	-1.39	[-.10, .02]	.173

Note. *SE* = standard error, CI = confidence interval. All moderators were entered in one model. There are 261 correlations and 96 independent samples. Between-study sampling variance (τ^2) is .02.

Table 6

Moderators of the Correlations Between Math and Language Interests

Moderator	<i>b</i>	<i>SE</i>	<i>t</i>	95% CI	<i>p</i> value
Grade level	-.04	.011	-4.05	[-.07, -.02]	< .001
Geographic location (reference group: United States)					
Asia	-	-	-	-	-
Australia	.16	.160	1.01	[-.19, .52]	.334
Canada	.07	.187	0.37	[-.44, .50]	.718
Europe (except Germany)	-.09	.153	-0.57	[-.53, .30]	.582
Germany	.06	.134	0.47	[-.40, .37]	.653
Response format (reference group: likert statement)					
Likert item-specific	-.06	.158	-0.36	[-.58, .34]	.732
Others	.05	.204	0.25	[-.54, .57]	.815
Index for calculating <i>r</i> (reference group: latent score)					
Observed score	.12	.130	0.96	[-.17, .54]	.376
Types of data (reference group: cross-sectional)					
Longitudinal	-.03	.093	-0.36	[-.32, .20]	.728

Note. *SE* = standard error, CI = confidence interval. All moderators were entered in one model.

Results are not reported if degrees of freedom are less than 4.00. There are 71 correlations and 43 independent samples. Between-study sampling variance (τ^2) is .03.

Table 7

Robustness of Grade Level Moderation of the Correlations Between Math and Language Motivational Beliefs Across Subgroups

Group	<i>b</i>	<i>SE</i>	<i>t</i>	95% CI	<i>p</i> value	τ^2
Overall	-.05	.005	-9.51	[-.06, -.04]	< .001	.03
Construct						
Ability self-concept	-.06	.007	-9.70	[-.08, -.05]	< .001	.02
Interest	-.05	.009	-5.77	[-.07, -.03]	< .001	.02
Self-concept	-.04	.007	-5.50	[-.05, -.02]	< .001	.03
Self-efficacy	-.03	.026	-1.33	[-.10, .03]	.223	.03
Task values	-.05	.016	-2.94	[-.09, .00]	.038	.03
Geographic location						
Asia	-.09	.036	-2.55	[-.17, -.01]	.032	.06
Australia	-.07	.012	-5.89	[-.10, -.04]	< .001	.02
Canada	-.06	.014	-4.28	[-.09, -.02]	.006	.04
Europe (except Germany)	-.02	.020	-1.17	[-.08, .03]	.296	.03
Germany	-.04	.006	-7.52	[-.06, -.03]	< .001	.02
United States	-.04	.010	-3.70	[-.06, -.01]	.004	.03
Response format						
Likert statement	-.05	.006	-9.22	[-.07, -.04]	< .001	.02
Likert item-specific	-.03	.010	-2.51	[-.05, -.01]	.023	.07
Others	-.03	.022	-1.33	[-.09, .03]	.246	.06
Index for calculating <i>r</i>						
Latent score	-.06	.007	-7.79	[-.07, -.04]	< .001	.02
Observed score	-.04	.006	-6.20	[-.05, -.03]	< .001	.03
Types of data						
Cross-sectional	-.05	.006	-8.77	[-.06, -.04]	< .001	.04
Longitudinal	-.04	.008	-5.51	[-.06, -.03]	< .001	.02

Note. *SE* = standard error, CI = confidence interval. Analyses were conducted in datasets separated by different moderators except for the overall group for which we used the complete dataset. The grade level was entered as the only predictor in each model. Results are not reported if degrees of freedom are less than 4.00.

Figure 1. Flow diagram for the search and inclusion criteria for studies in this review.

Figure 2. Scatterplot of grade level on the correlations between math and language motivational beliefs. The solid line is the best-fitting line for the robust variance estimation (RVE) meta-regression model without controlling for other moderators (for model estimates, see the row of “overall” in Table 7). The grey area represents the 95% confidence band of the model.

Figure 3. Scatterplot of grade level on the correlations between math and language ability self-concepts. Longitudinal = longitudinal data points, Same article = multiple waves of cross-sectional data points within the same article.

Figure 4. Scatterplot of grade level on the correlations between math and language interests. Longitudinal = longitudinal data points, Same article = multiple waves of cross-sectional data points within the same article.

Figure 5. Scatterplot of grade level on the correlations between math and language self-concepts. Longitudinal = longitudinal data points, Same article = multiple waves of cross-sectional data points within the same article.

Figure 6. Scatterplot of grade level on the correlations between math and language self-efficacies. Longitudinal = longitudinal data points, Same article = multiple waves of cross-sectional data points within the same article.

Figure 7. Scatterplot of grade level on the correlations between math and language task values. Longitudinal = longitudinal data points, Same article = multiple waves of cross-sectional data points within the same article.