Sibling Dynamics in Academic Socialization Within the Family Context

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Abstract

When it comes to academic socialization in the family context, many studies have addressed how parents influence their children's educational outcomes (Jeynes, 2003), and a number of studies have shown that the ways in which parents influence their children's educational outcomes differ by the macro influences of socioeconomic status or culture (Kim et al., 2020; Yamamoto & Sonnenschein, 2016). In comparison, less is known about the dynamics of academic socialization by individual children within a family.

Eccles and colleagues (Eccles, Arberton, et al., 1993) proposed a model of family influences on children's motivation and achievement. The model hypothesized the joint influence of family characteristics and child/sibling characteristics on parents' beliefs and behaviors, which in turn affect children's educational development. The model highlighted bidirectional influences not only between parents and children but also between siblings. Whereas most relevant studies and reviews of the model (Eccles, 2007; Wigfield et al., 2015) have centered on effects of family characteristics and parents' beliefs and behaviors on children's educational outcomes, the current dissertation alternatively focused on the hypothesized effects of a child's characteristics on parents and on the child's own academic self-concept as well as siblings' academic self-concepts.

Drawing from the model suggested by Eccles and colleagues (Eccles, Arberton, et al., 1993), I tested four hypotheses in the current dissertation. First, I constructed hypotheses about each child's individual experiences as well as a sibling's shared experiences with their parents in the family. Second, I hypothesized effects of each individual child's achievement on their own academic self-concepts and their sibling's academic self-concepts. Third, I hypothesized effects of each individual child's achievement and motivation on their parents' beliefs and parental support. Fourth, I focused on effects of sibling resemblance on comparison processes between siblings and parents' similar or differential support for the siblings' learning. To address the four hypotheses, the current dissertation included three empirical studies.

The first study (*Sibling Achievement as an Additional Frame of Reference for Parents' Beliefs About Each Child's Academic Ability*) focused on parents' beliefs about each sibling's academic abilities. To provide empirical evidence for parents' child-specific ability beliefs, the first study used secondary data (Gladstone et al., 2018) from 95 families collected in two academic-track secondary schools in a rural area of Germany and examined how much variance in parental beliefs could be explained by each parent's child-specific response compared with the variance present at the child, parent, and family levels. To investigate the formation of parents' child-specific ability beliefs, the study further addressed effects of siblings' achievement on parents' beliefs about each child's academic ability. We

explored whether each parent used the other sibling's achievement as an additional frame of reference for their beliefs about a child's abilities within and across domains by applying the internal/external frame of reference (I/E) model (Marsh, 1986b; Möller & Marsh, 2013). The results of a multilevel analysis showed substantial variance in parents' beliefs at all levels of influence within the family. More specifically, parents' beliefs about children's academic abilities varied on the family level, indicating that parents' beliefs differed from one family to another; varied on the parental level, indicating that parents' general beliefs about siblings' academic abilities differed between the mother and father; varied on the sibling level, indicating that both parents' child-specific beliefs differed between siblings; and varied on the level of each child, indicating that each parent's child-specific beliefs differed between siblings. These findings newly verified the hierarchical structure of parents' child-specific beliefs about children's academic abilities influenced by the multiple levels of influence from different socialization agents within the family. Additionally, the study provided tentative evidence that both the mother and father used each child's own achievement and their sibling's achievement as frames of reference for their beliefs about the child's academic abilities within and across domains, yet the results did not show the clear pattern of the I/E model (Marsh, 1986b; Möller & Marsh, 2013). Overall, the findings of the first study are in line with the hypotheses proposed by Eccles and colleagues (Eccles, Arberton, et al., 1993).

The second study (*Why Do Siblings Differ in Their Learning Motivation and Perceptions of Parental Support? Reciprocal Relationships Between Parental Support and Each Sibling's Learning Motivation*) investigated whether the reciprocal associations between diverse dimensions of perceived parental support (parents' expectations, parents' emotional support, parents' learning encouragement, and parental control) and children's learning motivation differed between siblings. Using data from 2,082 school-aged twins collected at age 11 and age 13, we tested reciprocal associations within and between twin pairs across the 2 years, holding individual children's characteristics of sex, school grades, and personality traits constant. By comparing monozygotic (MZ) and dizygotic (DZ) twins, we further verified whether the resemblance between siblings affected the reciprocal associations in within- and between-pair regressions. The results showed that there were significant reciprocal associations between an individual child's perceptions of their parents' learning encouragement and their learning motivation across ages 11 and 13, but only in the within-twin-pair regression for DZ twins. This means that the reciprocal relationships differed within DZ twin pairs, indicating the siblings' individualized academic socialization with parents across the 2 years. Such effects were not observed for the other dimensions of parental support or for MZ twins. MZ and DZ twins differed in particular in effects of learning motivation at age 11 on their perceptions of parents' learning encouragement at age 13. The substantial differences between MZ and DZ twins signified the

effects of sibling resemblance on how parents supported the siblings in similar or different ways. Overall, the findings point to motivational dynamics and each child's individualized interactions with their parents within the family.

The third study (*What Happens With Comparison Processes When "the Other" is Very Similar? Academic Self-Concept Formation in Twins*) investigated effects of individual children's and their siblings' achievement on their academic self-concepts, using data from 4,208 twins at age 11 and age 17. Applying the I/E model (Marsh, 1986b), the third study examined whether twin's and co-twin's academic achievement affected individual twin's academic self-concept within and across domains. In addition, the study further compared MZ with DZ twin pairs to determine whether they differed in co-twin's achievement effects on twin's academic self-concept to test whether sibling resemblance moderates social comparison processes within twin pairs, in line with social comparison theory (Festinger, 1954). Drawing on the pattern suggested by the I/E model, both MZ and DZ twins used their own achievement as a frame of reference for their academic self-concepts within and across domains (Marsh, 1986b). Yet, only MZ twins further used their sibling's achievement as an additional frame of reference for their academic self-concept within and across domains, showing the similar I/E pattern in effects of their own achievement on their academic self-concept. This finding provided new empirical evidence for a strong assimilation within perfectly similar sibling pairs, which is referred to and theorized as a mirror effect in the current study. Despite being similar to each other, DZ twins did not show the mirror effect but showed sibling deidentification or nonreferencing (Whiteman et al., 2007; Whiteman, McHale, et al., 2011) because they did not consider their sibling's achievement as a frame of reference for their academic self-concept within and across domains.

Overall, the findings from the three studies showed the reciprocal effects of individual children's and sibling's achievement and learning motivation on their academic socialization from their parents and their academic self-concepts. Accordingly, the studies provided empirical support for the four hypotheses and for the model of family influences on children's motivation and achievement proposed by Eccles, Arberton, et al. (1993). From a theoretical perspective, the studies produced new insights into the effects of children's characteristics on the diversity in academic socialization between siblings, which has garnered relatively little attention to date. In addition, by conducting interdisciplinary research, the dissertation showed the relevance and usefulness of applying the I/E model and the transactional model of parenting to address how children's and siblings' characteristics reciprocally affect parenting and children's educational outcomes. From a methodological perspective, multilevel analysis, cross-lagged modeling, and multiple-group analyses within a family are suggested to investigate dynamic academic socialization within the family. The

dissertation suggests a new perspective on the model proposed by Eccles and colleagues (1993) and the best method to investigate dynamic academic socialization within the family.

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Introduction

Dynamic Academic Socialization Within the Family

As children experience socialization processes initially and primarily in the family context (Rosen & D'Andrade, 1959), a child's family serves as an important context for the child's academic socialization. The influence of the family on children's academic achievement and motivation is a recurring theme throughout the education literature. Prominent theories of achievement motivation, such as expectancy-value theory (Eccles, 2007; Eccles et al., 1983) and self-determination theory (Grolnick et al., 1997; Grolnick & Ryan, 1989; Grolnick et al., 1991) have highlighted the importance of parents' practices/beliefs on students' achievement motivation and academic achievement. Numerous empirical findings in the field of education have accordingly focused on the associations between parents' practices and students' academic achievement (for a review and meta-analyses, see Boonk et al., 2018; Jeynes, 2003, 2007) as well as students' achievement motivation (Parsons et al., 1982; Urdan et al., 2007).

To investigate effects of the family environment on children's educational outcomes, education researchers have often focused on how parents' beliefs and behaviors differ from one family to another and are influenced by sociocultural factors outside the family (Bronfenbrenner, 2005), such as socioeconomic status (Bempechat & Shernoff, 2012; Song & Hattie, 1984), cultural background (for a review, see Kotchick & Forehand, 2002), and immigrant status (for a meta-analysis, see Kim et al., 2020). For instance, studies have shown how families from different socioeconomic groups create different learning environments at home, which affect children's achievement motivation (Song & Hattie, 1984). In addition, many empirical studies on academic socialization within the family context have centered on the parent-child relationship (for a review, see Taylor et al., 2004) except for a few studies on academic socialization between siblings (e.g., Wang et al., 2019). Subsequently, much has been learned about how the influence of parents on children's achievement and motivation varies across different families.

Prior studies on relationships between parenting practices and children's educational outcomes have had the same viewpoint and research focus. The studies typically used the responses from a child and a parent to represent the family's general parenting practices and educational outcomes. Accordingly, the studies examined the diversity in academic socialization between different families more than within families. In addition, many prior studies have typically assumed a unidirectional influence from parents to children, and thereby, the successful transmission of the extent to which parents value education and their educational support were emphasized for children's educational performance and outcomes (Boonk et al., 2018; Jeynes, 2003). In previous studies that

were based on the transmission model of family influences (Boonk et al., 2018; Jeynes, 2003), children in the same family were assumed to be influenced in similar ways by the general parenting practices and behaviors of their parents. At the same time, children were often viewed as passive recipients of parental influences in the studies.

However, despite our general belief that there are shared influences within the family, children in the same family sometimes experience their family differently. Individual parents treat siblings differently, siblings influence one another in different ways, and sometimes individual children perceive social influences in different ways (Plomin & Daniels, 2011; Weiner, 1972), as has been reported by both parents and siblings (Daniels et al., 1985). This focus led to the important recognition that siblings' experiences within the family cannot be characterized as just one experience (Furman & Lanthier, 2002). Siblings have different perspectives and experiences in their relationships with each other and form diverse relationships with their parents (Furman & Lanthier, 2002). Accordingly, an analysis of siblings' individual and shared experiences in the family is necessary to understand how intrafamilial influences contribute to an individual child's educational development (Plomin & Daniels, 2011). Furthermore, empirical findings have consistently shown that each sibling's individual experiences in the family largely contribute to their academic achievement and achievement motivation, more so than siblings' shared experiences in the family (Dunn & Plomin, 1990; Plomin & Daniels, 2011; Scarr & Weinberg, 1983). In this regard, it is important to verify which nonshared intrafamilial experiences that siblings have are related to their development (Turkheimer & Waldron, 2000).

On the other hand, from the viewpoint of the transactional model (Bell, 1968; Sameroff, 2009), an individual child is not only a recipient of social influences but is also an active socializer who can reciprocally affect the social influences that they receive and an agent who can shape their environment accordingly (Kuczynski & Parkin, 2007; Sameroff, 1994, 2009; Sameroff & Fiese, 1990). An increasing number of studies based on the transactional model of family influence have highlighted interactive influences in the parent-child relationship (Kuczynski & Navara, 2006; Kuczynski & Parkin, 2007). This means that the direction of influence goes both from parents to children and from children to parents and is thus bidirectional (Sameroff, 1994, 2009). For instance, in one empirical study, not only did parenting influence children's cognitive development, but also, children's cognitive ability reciprocally affected parenting (Tucker-Drob & Harden, 2012), implying that children can also influence the quality of the parenting that they receive. Accordingly, the transactional model viewpoint guides our focus to a larger family context with more than one child in which each child reciprocally interacts with each parent (Briley et al., 2014). As siblings differ from each other, their

individual characteristics reciprocally influence their parents and diversify parents' beliefs and the extents to which each parent supports each child (Jensen & McHale, 2015a, 2017).

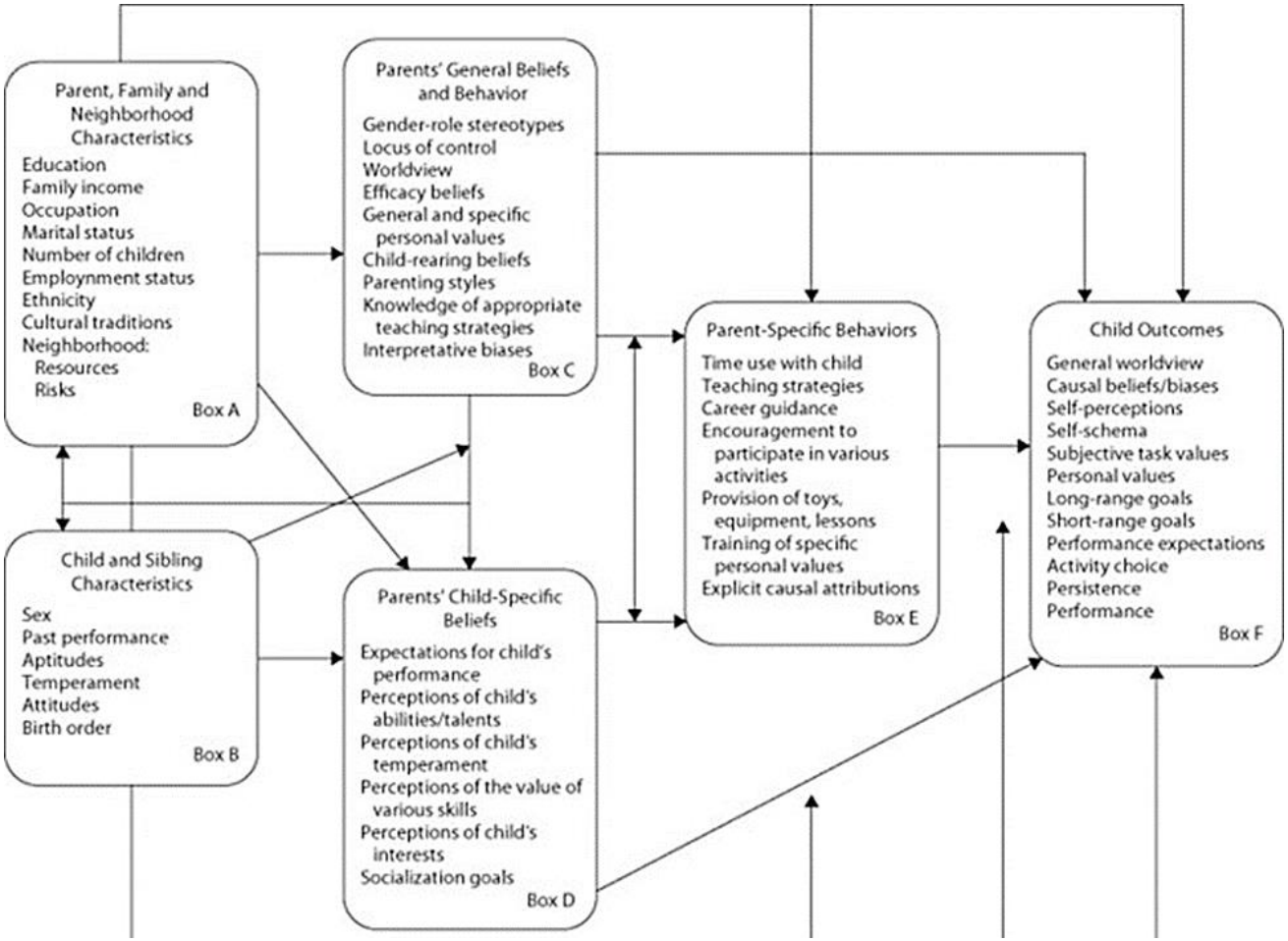
Corresponding to the empirical evidence for siblings' individual experiences in the family (Dunn & Plomin, 1990; Scarr & Weinberg, 1983) and the theories from the transactional model of family influences (Bell, 1968; Sameroff, 2009), Eccles and colleagues (Eccles, Arberton, et al., 1993) proposed a model of family influences on children's motivation and achievement, which hypothesized the joint influence of the family's demographic characteristics and characteristics of an individual child and a sibling on parents' child-specific beliefs and practices, which in turn affect children's educational outcomes (see Figure 1). Yet, from the model's viewpoint (Eccles, Arberton, et al., 1993), the mediational role of parents' beliefs and practices in the relationship between a family's demographic characteristics and children's educational outcomes has primarily been emphasized in the literature and in reviews of the model (Eccles, 2007; Wigfield et al., 2015; Wigfield et al., 2006), whereas the hypothesized effects of the characteristics of a child and a sibling on the dynamic academic socialization within the family have garnered relatively little attention. To move toward a more balanced view of the model, the current dissertation aims to provide theoretical and empirical support for the assumed effect of the characteristics of a child and a sibling on academic socialization in the family.

Taken together, the main theoretical perspective of this dissertation is expectancy-value theory, particularly the model of family influences on children's motivation and achievement (Eccles, 2007; Eccles, Arberton, et al., 1993). To address effects of the characteristics of a child and a sibling, I considered the larger family context with more than one child and employed the model to investigate dynamic academic socialization within the family. Drawing from the model (Eccles, Arberton, et al., 1993), this dissertation contains four main research aims. First, I aim to extend prior research on general parental influences on children's motivation by narrowing the focus to parents' beliefs and support that are specific to each sibling in the family. Accordingly, I review the literature on how parents' child-specific beliefs and child-specific support are associated with individual siblings' achievement-related motivation. Second, I aim to shed light on children as active agents of their own learning. For this, I review the relevant literature on the effects of an individual child's achievement, their motivation, and their sibling's characteristics on their academic self-concept. Third, I aim to investigate children's effects on parents. Hence, I review the literature on the reciprocal effects of children's achievement and motivation on parents' beliefs and support. Fourth, I aim to newly explore how sibling resemblance affects siblings' mutual interaction and parent-child interactions. More specifically, I consider the literature on siblings (Whiteman et al., 2009; Whiteman & Christiansen,

2008; Whiteman et al., 2007; Whiteman, McHale, et al., 2011) as well as social comparison theory (Festinger, 1954) to investigate how differences and similarities between siblings affect interactions between siblings and interactions between parents and siblings. To draw on the sibling resemblance effect, I considered twins as pairs and examined how the different degrees of resemblance between two types of twin pairs (monozygotic and dizygotic) affect sibling interactions as well as how parents treat the siblings. To this end, I aim to provide theoretical and empirical support for dynamic academic socialization within a family.

Figure 1.

Model of family influences on children's motivation and achievement.



1Source: In "Development of Achievement Motivation" (p. 969), by A. Wigfield, J. S. Eccles, U. Schiefele, R. W. Roeser, and P. Davis-Kean, in Social, Emotional, and Personality Development, N. Eisenberg (Ed.), 2006, Vol. 3 of the Handbook of Child Psychology.

1. Theoretical Background

Model of Family Influences on Children's Motivation and Achievement

By reviewing the existing literature on family influences on students' achievement motivation, Eccles and colleagues (Eccles, Arberton, et al., 1993) originally proposed a model of family influences on children's motivation and achievement (see Figure 1). I reviewed the relevant studies on family influences with respect to this model (Wigfield et al., 2015; Wigfield et al., 2006) with a central focus on the general childrearing climate, effects of parents' beliefs and practices on children's motivation and achievement outlined in Box C and Box D, and the family's demographic characteristics outlined in Box A (Eccles, 2007). The reviewed studies mostly centered on the association between demographic and cultural characteristics of the family on the one side and parents' beliefs or behaviors on the other (Wigfield et al., 2015). The studies also highlighted the roles of parents' beliefs and practices as mediators of the relationships between a family's demographic characteristics and children's engagement and performance in achievement-related settings (Wigfield et al., 2015). In view of the model, the emphasis has mainly been on the role that parents play in academic socialization in the family.

Although Eccles and colleagues (Eccles, Arberton, et al., 1993) stated that the theoretical model (see Figure 1) was proposed to explain the influence of the family on individual differences in students' motivation, the hypothesized effects of the characteristics of the child and siblings in the model have garnered relatively less attention in reviews of the relevant studies that have applied the model (e.g., Eccles, 2007; Wigfield et al., 2015). It is still the case that, other than several studies that have focused on the effect of a child's gender on parents' beliefs and the child's achievement motivation, very few studies have investigated the several components underlying the characteristics of the child and siblings outlined in Box B, such as past performance, aptitude, temperament, attitudes, and birth order (Eccles, 1994, 2011; Fredricks & Eccles, 2002; Kimmel et al., 2012; Parsons et al., 1982; Šimunović & Babarović, 2020). Accordingly, children's characteristics, such as attitude and prior achievements (Box B), have been interpreted and described as merely effects of "exogenous characteristics" on parents' beliefs or children's outcomes (p. 678, Wigfield et al., 2015).

With the current dissertation, my goal is to shift the focus toward how the characteristics of the child and siblings affect parenting as well as the child's own motivation and outcomes by shedding light on the relatively unexplored areas of the model (Eccles, Arberton, et al., 1993). Beyond the general discussion of the effects of parents' beliefs and practices on children's educational outcomes, in the current dissertation, I subsequently suggest alternative interpretations of the model proposed by Eccles and colleagues (Eccles, 2007; Eccles, Arberton, et al., 1993). Parents' child-specific beliefs

and practices (Boxes C and D) are assumed to be influenced by individual characteristics of the child and siblings (Box B) in the model (see Figure 1), thus signifying effects of the children on the parents. Moreover, the joint influence of a child's characteristics and siblings' characteristics on parents' beliefs and behavior implies individual child-level as well as sibling-level influences on parents' beliefs and behaviors. On the other hand, the hypothesized effects of the characteristics of the child and siblings (Box B) on the child's educational outcome (Box F) in the model (Eccles, Arberton, et al., 1993) call attention to academic socialization processes between siblings. From the viewpoint of the current dissertation, the theoretical model draws on how individual children, their siblings, and their parents co-create the dynamics of academic socialization within the family.

Consequently, the current dissertation employed the theoretical model (Eccles, 2007; Eccles, Arberton, et al., 1993) to investigate academic socialization in families with more than one child, in which an individual child interacts with their siblings and with each parent. Accordingly, I reviewed the relevant theories and literature to address topics that involve (a) differences between individual siblings in their experiences with and interactions with their parents, such as parents' child-specific beliefs and support for each child, (b) effects of children's academic achievement on their own motivation and a sibling's motivation, (c) effects of children's characteristics on their parents, and (d) effects of sibling resemblance on sibling interactions and parent-child interactions. To this end, the dissertation includes three empirical studies on the abovementioned topics. By providing theoretical and empirical support for the assumed effects of the characteristics of a child and a sibling on academic socialization within the family, I aim to emphasize that children are active socializers and agents of their own learning in the family context and present new perspectives on the model of family influences on children's motivation and achievement (Eccles, 2007; Eccles, Arberton, et al., 1993).

1.1. Parents' Child-Specific Beliefs and Support

Parents play a pivotal role in their children's educational development. In particular, parents' beliefs and behaviors are critical for providing various activities, resources, and stimulation for pursuing learning activities and accordingly setting the climate for the development of children's achievement motivation in the home environment (Wigfield et al., 2015; Wigfield et al., 2006). Meta-analyses have highlighted parental involvement (Castro et al., 2015; Fan & Chen, 2001; Jeynes, 2007), parents' educational expectations (Pinquart & Ebeling, 2020), and parents' autonomy support (Vasquez et al., 2016) as important antecedents of children's academic achievement. In addition, many studies have investigated the relationships between the diverse dimensions of parental support and children's motivation to learn (for a review, see Barger et al., 2019; Gonida & Urdan, 2007).

Investigating the associations between parenting practices and children's educational outcomes, parents' beliefs and behaviors have been emphasized as mediators of the relationships between family demographic characteristics (e.g., SES, ethnicity) and children's motivation and achievement (Kim et al., 2020; Wigfield & Eccles, 1992; Wigfield et al., 2015; Yamamoto & Sonnenschein, 2016). Accordingly, the associations between parents' beliefs, parental involvement, and children's educational outcomes have typically been investigated for individual students from different family backgrounds. However, when we consider academic socialization within families that have more than one child, it is critical to have a more precise understanding of parents' beliefs and support that are specific to the individual child above and beyond the general influences that parents are commonly believed to have on all siblings. Indeed, siblings' differential experiences with their parents have been empirically documented in a number of prior studies (Asbury et al., 2003; Daniels & Plomin, 1985; Rowe & Plomin, 1981; Turkheimer & Waldron, 2000). In this regard, in the current dissertation, I closely consider the within-family context and focus on parents' beliefs and support that are specific to each child compared with parents' general beliefs and support for all children in the family.

In this section, I review the literature on parents' beliefs that are specific to each child and parents' general beliefs about siblings' academic ability and parents' support for their children's learning, drawing on the model of family influences on children's motivation and achievement (Eccles, 2007; Eccles et al., 1983).

Levels of Parental Beliefs: Parents' Child-Specific Beliefs and General Beliefs About All Children

Parents hold general beliefs about their children as well as child-specific beliefs (Eccles, 2007). According to the model of family influences on children's motivation and achievement suggested by Eccles and colleagues (Eccles, 2007; Eccles, Arberton, et al., 1993), parents' general beliefs include

parents' gender stereotypes, efficacy beliefs, general parenting styles, child-rearing beliefs, and teaching strategies, all of which are hypothesized to be influenced by the exogenous family and neighborhood or cultural characteristics (Eccles, 2007; Wigfield et al., 2015). On the other hand, parents also hold child-specific beliefs, such as expectations about a child's performance, perceptions of the child's abilities, perceptions of the child's temperament, and socialization goals for each child (Eccles, 2007). According to the theoretical model (Eccles, 2007; Eccles, Arberton, et al., 1993), a parent's child-specific beliefs are influenced by the joint influence of the parent's general beliefs and the individual characteristics of each child (Eccles, 2007).

Regarding the effects of each individual child and siblings on parents' beliefs (Eccles, 2007; Eccles, Arberton, et al., 1993), parents should have child-specific beliefs about each sibling as well as general beliefs about all siblings. Considering each parent's interaction with each child (Parke & Buriel, 2007), parents should hold specific beliefs about each child either because the mother and father differ in their beliefs about each child or because the mother's and father's shared beliefs about each child differ between siblings. On the other hand, interactions happen at the group level within the family (Parke & Buriel, 2007), such that the mother and father have general/shared beliefs about the siblings. Such parental beliefs should also differ across different families. Parents' assumed child-specific and general beliefs reflect each parent's individual and shared experiences within the family, respectively (Parke, 2004; Parke & Buriel, 2007). In other words, the characteristics of each individual child are assumed to have an impact on parents' child-specific beliefs, whereas siblings' shared characteristics are assumed to have an impact on parents' general beliefs about siblings based on the model of family influences on children's motivation and achievement (Eccles, Arberton, et al., 1993). These theoretical viewpoints point to the hierarchical structure of parents' beliefs involving general, sibling, and individual child-level parental beliefs.

The hypothesized hierarchical structure of parental beliefs in the model of family influences (Eccles, Arberton, et al., 1993) corresponds to family systems theories (Parke, 2004; Parke & Buriel, 2007), which highlight diverse social systems within the family. According to family systems theories (Parke, 2004; Parke & Buriel, 2007), the interaction happens at the individual level among individual family members as well as at the group level, such as among siblings and parents (Oliva & Arranz, 2005). In this regard, multilevel analyses within the family are critical for investigating how multiple levels of interaction in the family diversely affect parental beliefs, thus resulting in parental beliefs that are specific to each child and general parental beliefs about siblings. More specifically, by examining the variance in parents' beliefs at the level of each child, it is possible to analyze the extent to which parents' beliefs differ for each child as well as how parents' shared beliefs about siblings

differ from one family to another. Accordingly, we can have a deeper understanding of the structure of parental beliefs in relation to the diverse levels of interaction within the family.

Analyses of the substantial variance in parental beliefs on the multiple levels of influence within the family are also important for a precise and consistent conceptualization of parental beliefs. Parents' beliefs have been inconsistently conceptualized and measured in the literature. Some studies have used the responses of either a mother or a father (Dai, 2002; Van Zanden et al., 2017), whereas other studies have aggregated the responses of the two parents to represent general parental beliefs (Wolff et al., 2020). Accordingly, the effects of individual children's academic achievement on parents' beliefs have differed across empirical studies. In this regard, a multiple-level analysis of parents' beliefs within a family has the potential to contribute to a consistent conceptualization of parents' beliefs as well as a precise investigation of their effects on siblings' educational outcomes.

Taken together, the hypothesized general and child-specific beliefs of parents in the model proposed by Eccles and colleagues (Eccles, 2007; Eccles, Arberton, et al., 1993) suggest insights into the hierarchical structure of parents' beliefs and possible diverse levels of influence within the family. When we consider different socialization agents, such as the individual child, their siblings, and each parent within the family, parents' child-specific beliefs are assumed to differ between siblings and between parents. This viewpoint suggests the possible conceptualization of parents' beliefs in accordance with the multiple levels of interactions within the family involving child-specific-, sibling-, parent-, and family-level influences, thus producing comparable findings across the studies of parental beliefs.

Effects of Parents' Beliefs on Parental Behavior

Parents' general beliefs and parents' child-specific beliefs are hypothesized to directly affect parents' behaviors, such as encouraging children to engage in learning activities (see Box D in Figure 1) in expectancy-value theory's model of family influences (Eccles, 2007; Eccles, Arberton, et al., 1993). Associations between parents' beliefs and behavior are especially important for understanding why parents support children's learning in a certain way. In the model (Eccles, Arberton, et al., 1993), parents' general beliefs are hypothesized to mediate effects of family characteristics (e.g., SES, ethnicity, and culture) on parents' behaviors (Wigfield et al., 2015). For instance, parents in different socioeconomic status groups may have different beliefs about parenting, which in turn means that they support their children differently. On the other hand, parents' child-specific beliefs are hypothesized to mediate the relationships between the characteristics of each child and parents' support for their children's learning (Wigfield et al., 2015). The mediated effect of the characteristics of each child on parents' behavior by parents' child-specific beliefs indicates that parents' behavior

and support will sometimes be child-specific and sometimes general for all siblings. Corresponding to the hypotheses illustrated in the model (Eccles, Arberton, et al., 1993), a qualitative research study showed that parents had different academic ability beliefs for each child, which in turn resulted in differentiated parental support and involvement for each child (Quadlin, 2019). Accordingly, several empirical studies have shown that children have a clear awareness of how their parents treat them differently than their parents treat their brothers and sisters (Boll et al., 2003; Brody et al., 1992; Kowal & Kramer, 1997; McHale et al., 2000). Nevertheless, very few studies have focused on relationships between parents' beliefs and behaviors, whereas most studies have separately addressed effects of parents' beliefs and support on students' educational achievement and motivation (Dinkelmann & Buff, 2016; Šimunović & Babarović, 2020). In this regard, the association between parents' beliefs and support remains an important avenue for research.

Effects of Parents' Beliefs on Children's Achievement and Motivation

Parents' child-specific beliefs are hypothesized to affect not only parents' behavior but also children's educational outcomes, such as academic self-concept, educational choice, persistence, and performance (Eccles, 2007). In particular, parents' beliefs about their children's academic abilities have an actual influence on children's evaluations of their academic ability, namely, academic self-concept (Frome & Eccles, 1998; Gniewosz et al., 2012). Empirical findings have shown that parents' beliefs and perceptions of their children's academic ability impact their children's academic self-concept, independent of the parents' own achievement (McGrath & Repetti, 2000). Furthermore, parents' beliefs have been found to have a powerful impact on children's academic self-concept across different timepoints in their school careers, including primary school (Frome & Eccles, 1998; Simpkins et al., 2012) and secondary school (Fredricks & Eccles, 2002; Gniewosz et al., 2012; Simpkins et al., 2012). Theoretically, it might be the case that, when evaluating themselves, individual students take into consideration how significant others evaluate them (Harter, 1988), and thereby, when parents believe that their children are high performers in early childhood, this sets a meaningful foundation for self-confidence and high academic achievement (Dweck, 1986; Dweck & Master, 2009).

Based on the robust empirical findings on how parents' beliefs about their children's academic abilities are associated with students' academic functioning and educational outcomes (for a meta-analysis see, Pinquart & Ebeling, 2020), parents' different beliefs about each sibling's academic ability would be an important factor for further differentiating siblings' educational outcomes. Accordingly, in an empirical study, when parents had higher beliefs about a child's academic ability than about the child's sibling, a higher grade was predicted for the target child the following year when controlling for siblings' average grades and the differences in siblings' previous achievements (Jensen & McHale,

2015b). In these regards, parents' beliefs about child-specific ability are an important factor that creates a different learning environment and parental support for the siblings and would thereby further contribute to differences in siblings' educational development.

Effects of Parental Support on a Sibling's Learning Motivation

Parents provide diverse support for fostering children's motivation at home. For instance, parents' behavioral support (e.g., helping with homework), affective support (e.g., parental aspirations and expectations), and parent-child relationships have been found to be associated with children's achievement-related motivational constructs and learning behaviors in school (Barger et al., 2019; Gonida & Urdan, 2007; Pomerantz et al., 2012; Pomerantz & Moorman, 2010 ; Pomerantz et al., 2007; Pomerantz, Wang, et al., 2005; Urdan et al., 2007). Expectancy-value theory has correspondingly highlighted the importance of parental support, especially for its impact on children's intrinsic learning value and motivation (Wigfield et al., 2015).

Intrinsic academic motivation refers to students' enjoyment of learning in school and engaging in activities for their own sake, such that pleasure is inherent in the learning activity itself (Gottfried, 2019). Thus, an individual student's belief in the intrinsic value of learning is a desirable educational outcome and has unique importance for students' future academic success across different school contexts and different cultures (Taylor et al., 2014). According to self-determination theory (SDT), three innate psychological needs of students are important for developing their intrinsic and autonomous motivation. In SDT, it was suggested that individual children's needs for competence, social relatedness, and autonomy should be fulfilled in the learning context in order to ensure that children will have the intrinsic motivation to learn (Deci & Ryan, 2000). Specifically, children should be able to have a sense of control over their own learning behavior and educational goals, thus enabling them to feel a sense of self-determination (Ryan & Deci, 2000). In addition, children should be able to feel competent when implementing tasks and should learn different skills so that they can initiate the actions that will help them achieve their own goals (Ryan & Deci, 2000). Finally, children need to have a sense of belonging to the people around them (Ryan & Deci, 2000). Studies based on SDT highlight the importance of providing the social support that is aimed at satisfying the psychological needs of children to foster intrinsic, autonomous learning motivation (Deci, 1975; Deci & Ryan, 2000; Grolnick et al., 1997; Grolnick et al., 1991; Ryan & Deci, 2000).

Accordingly, a child's internalization of the value of intrinsic learning depends on parenting methods (Grusec & Goodnow, 1994). The interplay of parental involvement and interest in the child's activities, parental support for autonomous behaviors, and adequate structures are emphasized for promoting the autonomous learning motivation of children and adolescents (Grolnick et al., 2002).

Parents' support for children's autonomous learning, such as a mother's emphasis on effort and learning strategies while helping children with homework (Pomerantz, Grolnick, et al., 2005), is particularly important for children to feel socially supported and competent. Interestingly, children's achievement levels were found to moderate the effects of parents' autonomy support and parental control on children's academic performance such that low achievers were more positively influenced by parental autonomy support but were negatively influenced by parental control (Fei-Yin Ng et al., 2004). In addition, children's motivational variables (i.e., understanding of self-regulation, perceived competence, and perceived autonomy) generally mediated the effect of children's perceptions of their parents' support and involvement and children's school performance (Grolnick et al., 1991). These empirical findings are in line with the hypothesized effects of children's characteristics on the associations between parents' behaviors and children's educational outcomes in the model of family influences by Eccles and colleagues (Eccles, Arberton, et al., 1993).

Based on effects of parental support for autonomous learning on children's educational outcomes as moderated or mediated by individual children's achievement and motivation (Fei-Yin Ng et al., 2004; Grolnick et al., 1991), parents' support may differ across siblings. Such differentiated parental support for each sibling's autonomous learning would further influence siblings' differential educational motivation and achievement. Empirical studies have shown differentiated parental support and involvement across siblings (Quadlin, 2019) and siblings' perceptions of parents' differential treatment (Brody et al., 1992; Kowal & Kramer, 1997; McHale et al., 2000). At the same time, parents' gender also plays a role in the extent to which parenting differs across siblings. Compared with fathers, mothers were more likely to differentiate between children within a pair of MZ or DZ twins in areas such as consistency and monitoring. It was also assumed that mothers were more intimately familiar with the individuality of each sibling (Cohen et al., 1977). In this regard, the association between parents' different support of siblings and the differences across siblings in educational motivation should be addressed further by considering each sibling's individuality in their motivation and achievement as well as parents' characteristics.

1.2. Effects of Children's Characteristic on Their Educational Outcomes

According to the model of family influences by Eccles and colleagues (Eccles, 2007; Eccles, Arberton, et al., 1993), not only parents' beliefs and behaviors but also characteristics of each individual child, such as gender, age, past performance, aptitude, temperament, birth order, interests, and ability self-concepts (i.e., Box B in Figure 2), are hypothesized to have a combined influence on each child's own educational outcomes, such as their perceptions of their own academic abilities and their academic performance. The viewpoint of the model that children with high achievement or who appear to strive for achievement should display certain characteristics, such as past performance, academic interests, and ability self-concept, points to reciprocal relationships between achievement and achievement-related motivation (Chamorro-Premuzic et al., 2010; Marsh et al., 2005a; Wigfield & Karpathian, 1991). For instance, individual children tend to have a higher academic self-concept when their prior achievement is higher, but also, high-achieving children tend to have a higher academic self-concept in the respective domain, whereas the academic self-concepts of children with lower levels of achievement tend to decrease over time (Chamorro-Premuzic et al., 2010). The theoretical model (Eccles, Arberton, et al., 1993) and empirical findings (Marsh et al., 2005a; Wigfield & Karpathian, 1991) have consistently suggested that motivation and achievement should be viewed as determinants as well as consequences of educational development.

Even more interestingly, sibling characteristics are assumed to affect individual children's educational outcomes in the model (Eccles, Arberton, et al., 1993). This indicates a mutual influence between siblings in how individual children's characteristics have an impact not only on their own educational outcomes but also on their siblings' educational outcomes. However, very few studies have addressed how sibling characteristics, particularly their academic achievement, affect another sibling's academic self-concept in the process of learning. Indeed, siblings are likely to be comparison targets for each other as they are constantly faced with mutual comparisons and companionship in the family context (Whiteman, Bernard, et al., 2011; Whiteman et al., 2007; Whiteman, McHale, et al., 2011). In particular, such comparison processes are assumed to have a greater influence on same-aged siblings (i.e., twins) regarding their close physical and emotional proximity and the fact that they are in the same developmental phase (Fortuna et al., 2010). In this regard, I will now proceed to review the relevant literature on the effects of individual children's achievement on their own academic self-concept as well as their siblings' academic self-concept.

Effects of Individual Children's Achievement on Their Academic Self-Concept

Self-concept refers to the set of perceptions or references that individuals have about themselves (Marsh et al., 2017; Marsh & Yeung, 1997). Individuals construct their self-concepts by collecting information about attributes, qualities, weaknesses, capacities, and values with respect to

their identity (Marsh et al., 2017; Marsh & Yeung, 1997). In the learning context, students form their academic self-concepts by incorporating diverse frames of reference or evaluation standards (Marsh, 1987; Skaalvik & Skaalvik, 2002; Wolff et al., 2018) involving an absolute ideal standard (e.g., achieving a perfect grade on a math exam), a comparison target based on social comparisons from the school or home context (e.g., classmates' school grades), dimensional comparisons (e.g., one's accomplishments in one domain relative to one's own accomplishments in other domains), and temporal comparisons (e.g., improvement over time, a personal best). In addition, individual students take into consideration significant others' evaluations of their academic ability (Harter, 1988, 2003). Therefore, individual students use the various frames of reference from their educational situation to construct their academic self-concepts in each academic domain (Marsh & Martin, 2011; Wolff et al., 2018).

Academic self-concept has two main academic facets from the verbal and math domains (Marsh, 1990c; Shavelson et al., 1976). Accordingly, the internal/external frame of reference (I/E) model was suggested to explain the differentiated development of math and verbal self-concepts regarding math and verbal achievements (Marsh, 1986b; Marsh et al., 1988). The I/E model describes how individual children's comparisons of their math and verbal achievements impact the formation of their math and verbal self-concepts within and across domains (Marsh, 1986b; Möller et al., 2020).

For the internal frames of reference, they internally compare their achievement in a certain domain with their achievement in another domain to develop their academic self-concepts in different academic domains (Marsh et al., 2014). Specifically, the downward comparison of a person's higher achievement in a certain domain with their lower achievement in another contrasting domain enhances their academic self-concept, whereas the upward comparison of a person's lower achievement in a certain domain with their higher achievement in a contrasting domain decreases their academic self-concept (Marsh et al., 2014). For instance, empirical studies of the dimensional comparison process have shown that an individual student's higher achievement in verbal subjects next to poorer math achievement increases their verbal self-concept (Möller et al., 2020). Conversely, a student's higher math achievement along with poorer verbal achievement increases their math self-concept (Möller et al., 2020). On the other hand, when individuals perceive similarity between two academic subjects, such as math and physics, their academic self-concept in each subject will be less differentiated than their comparison of their achievements between the contrasting domains of math and English (Helm et al., 2016).

For external frames of reference, students socially compare their achievement with other students' achievements in a given domain (Möller et al., 2020). In doing so, the downward comparison

of one's achievement with lower achieving others enhances a person's academic self-concept, whereas the upward comparison of a person's achievement with higher achieving others decreases the person's academic self-concept in the respective domain (Marsh, 1986b; Möller et al., 2020). Many studies have investigated how individual students construct their academic self-concept by comparing their achievements in the school context. In the school context, contrast effects prevail among students (Trautwein & Möller, 2016). When compared with higher achieving others or a reference group or class, individual students tend to have lower academic self-concepts (Möller et al., 2020). Findings on the effects of contrasts on students' academic self-concepts have consistently been reported across different cultures and times (Seaton et al., 2013).

On the other hand, a few studies have reported an unusual positive assimilation among students regarding their sense of the standing of their class or school (among others) and the reflected glory effect (Seaton et al., 2008; Trautwein, Lüdtke, Marsh, et al., 2009). More specifically, controlling for an individual student's own achievement, the higher standing of their class slightly buffered effects of negative comparisons on an individual student's academic self-concept (Trautwein, Lüdtke, Marsh, et al., 2009). It was speculated that students' sense of belonging or group identity may have fostered the assimilation of individual students to regard the success of their class or school for their own academic self-concept, controlling for the negative contrast effects (Trautwein, Lüdtke, Marsh, et al., 2009). Yet, many of the studies reported a stronger contrast effect than assimilation effects in the school context (Marsh, Seaton, et al., 2008). Nevertheless, given that both contrast and assimilation effects on academic self-concept have been observed (Seaton et al., 2008), identifying what moderates these effects is the priority of research that is aimed at understanding individual differences in academic self-concept formation. As comparison effects depend on whether students perceive high-achieving comparison targets or groups as reflected glory or as a threat to their academic self-concept (Seaton et al., 2008), it is reasonable to investigate further which factors differentiate individual students' perceptions of comparison targets.

Compared with older students, younger students tend to have higher academic self-concepts, and their academic self-concepts are less differentiated across academic domains (Marsh, 1990a; Weidinger et al., 2019). However, as they gain more insights into their interests and career paths, their interests in pursuing achievement in each academic domain tend to be more differentiated. In parallel, students learn more about the strengths and weaknesses of their academic ability throughout the social processes in the diverse educational context (Marsh, 1990a; Weidinger et al., 2019). Accordingly, in the transition to middle school, students' beliefs in their abilities and their valuing of different academic subjects become more balanced and have a closer correspondence with their achievement levels and needs (Eccles et al., 2006; Eccles et al., 1989). Taken together, the development of academic

self-concept differs by students' age regarding their social experiences, cognitive development, and identity formation (Eccles et al., 1989; Wigfield, 1994; Wigfield et al., 2015; Wigfield et al., 2006; Wigfield & Karpathian, 1991).

Effects of Individual Children's Achievement on Their Siblings' Academic Self-Concepts

According to the model of family influences on children's motivation and achievement, in a family with more than one child, sibling characteristics have an impact on each other child's educational outcomes (Eccles, 2007; Eccles, Arberton, et al., 1993). Although the influence of siblings on a child's development has been researched by psychologists (Piaget, 1932; Sullivan, 1953), family systems theorists (Minuchin, 2002), and behavioral geneticists (Daniels & Plomin, 1985; Plomin & Daniels, 2011; Rowe & Plomin, 1981; Scarr & Weinberg, 1983), empirical studies in the field of education have paid relatively less attention to how sibling characteristics affect students' educational motivation and achievement.

In their shared family environment, siblings compare their power, competencies, and responsibilities with each other (Schachter et al., 1976; Whiteman, McHale, et al., 2011). Thus, social experiences with siblings powerfully affect individual children's self-concept formation (Whiteman, McHale, et al., 2011). Siblings' interactions show dynamic socialization processes. Children imitate and try to learn from their siblings, they deidentify with or try to differentiate themselves from each other, and some siblings decide not to compare themselves with each other (Whiteman et al., 2007). It was hypothesized that siblings would differentiate themselves from (or deidentify with) each other and develop different attributes and behaviors (Sulloway, 1996; Whiteman et al., 2009) to reduce their competition with each other (Schachter et al., 1976; Sulloway, 1996; Whiteman, McHale, et al., 2011). On the other hand, siblings occasionally identify with and imitate each other in social learning (Tesser, 1980) and develop similar traits and behaviors termed sibling identification (Whiteman et al., 2007). Accordingly, empirical findings have shown that siblings often intensify either similarities or differences between them throughout their development (Whiteman, Becerra, & Killoren, 2009; Whiteman, McHale, & Crouter, 2007).

Interestingly, the extents to which siblings deidentify and identify with each other (Whiteman et al., 2007) are comparable to empirical findings on social contrasts and assimilation among students in the school context (Huguet et al., 2009; Seaton et al., 2008; Trautwein, Lüdtke, Marsh, et al., 2009). In an empirical study, similar to students in the school setting, siblings showed contrast effects in their relative achievement on their academic self-concepts (We & Park, 2011). A different viewpoint suggested that an individual child is more likely to use a high-achieving sibling as the salient role model for social learning in which they positively develop their academic self-concept and similar

characteristics throughout their educational development (Bandura, 1977). In a study that investigated families with two adolescent children (11- to 15-year-olds), both older and younger siblings were characterized by modeling processes and supportive relationships (Branje et al., 2004). In the learning context, school-aged siblings helped with a younger sibling's homework, modeled each other's academic behaviors, and assimilated other siblings' educational motivations and values (Nicoletti & Rabe, 2019). Accordingly, older and younger siblings have shown similar levels of school achievement (Nicoletti & Rabe, 2019; Oettinger, 2000). Taken together, social contrasts and assimilation should be the relevant comparison processes for siblings' academic self-concept formation.

Regarding the assumed effects of comparing one's own achievement with one's siblings' achievement on one's academic self-concept, it makes sense to also ask about how academic self-concept is affected when siblings who are the same age (i.e., twins) compare their own achievement with their sibling's achievement. As twins go through the same developmental phase at the same time (Fortuna et al., 2010), twins are likely to perceive each other as a comparison target. Co-twins sometimes serve as a comforting influence, thus fostering mutual companionship, but they also serve as a direct and constant comparison target, and twins thereby compete with each other (Fortuna et al., 2010; Fraley & Tancredy, 2012; Segal & Knafo-Noam, 2018). Investigating nationally representative samples of Finnish twins, the dependence between twin and co-twin had an impact on their educational attainment, yet co-twin dependence differed by zygosity and gender (Penninkilampi-Kerola et al., 2005). This finding implies a substantial influence of the relationship with the co-twin on an individual twin's achievement. Based on these findings, it is reasonable to assume that co-twins' achievement should provide an additional frame of reference for an individual twin's academic self-concept. In addition, as twins are same-age siblings, it enables researchers to investigate the bidirectional or mutual influence of effects of achievement on academic self-concept within sibling pairs irrespective of their birth order.

In comparisons of twins and nontwin siblings, there are some different as well as common characteristics in their interactions. Some studies have highlighted the difference between twins and non-twin siblings. As twins grow in the same developmental phase in which they regard each other as a companion concerning similarity in their traits and environment, the twin relationship is characterized by exceptional closeness and intimacy (Fortuna, Goldner, & Knafo-Noam, 2011). Beyond genetic similarity, socialization traits, such as empathy, including the other in the self, and shared experiences differentiate twinships from nontwin sibling relationships (Fraley & Tancredy, 2012). As twins get older, they are even more likely to be attached to their co-twins, unlike nontwin siblings (Fraley & Tancredy, 2012). On the other hand, like nontwin siblings, twins also show both sibling

assimilation and sibling deidentification as well as sibling rivalry (Fortuna et al., 2010; Fraley & Tancredy, 2012; Segal & Knafo-Noam, 2018). For instance, an empirical study showed that twins and nontwins did not differ in the frequency with which they used upward, downward, and neutral comparisons (Watzlawik, 2009). Therefore, an analysis of twins would provide insights into how similar siblings' comparisons of their academic achievement affect their academic self-concepts while holding their age gap and birth order constant. The comparison between monozygotic (MZ) and dizygotic (DZ) twins will further be elaborated on in Chapter 2.4.

1.3. Children's Effects on Parents

From an ecological systems theory perspective (Bronfenbrenner, 2005), a number of studies have provided insights into how the environmental context affects the development of parents' beliefs and behaviors by influencing the perceptions parents have of their own children (for a review, see Okagaki & Divecha, 1993). A previous review of parents' beliefs highlighted that the multiple factors within the parental context influence the development of parents' beliefs (Okagaki & Divecha, 1993). As for contextual factors outside the family, the review highlighted substantial influences of socioeconomic status, work, friends, neighbors, and the advice of experts (Okagaki & Divecha, 1993). Regarding factors inside the family, parents' characteristics, marital status, and the characteristics of the child were listed as factors that influence parents' beliefs (Okagaki & Divecha, 1993). Regarding effects of children's characteristics, a child's gender, age, and achievement were assumed to substantially affect parents' beliefs (Bell, 1968; Okagaki & Divecha, 1993).

Focusing specifically on academic socialization within the family, the model of family influences (Eccles, Arberton, et al., 1993) also hypothesized that characteristics of the child and siblings, such as sex, past performance, aptitude, temperament, attitudes, and birth order (i.e., Box B in Figure 1) would predict parents' diverse child-specific beliefs, such as expectations for the child's achievement and perceptions of the child's ability, perceptions of the value of various skills for the child, perceptions of the child's interests, specific socialization goals (i.e., Box D in Figure 1), as well as parental behaviors (Eccles, 2007; Eccles, Arberton, et al., 1993). Accordingly, the theoretical model proposed by Eccles and colleagues (Eccles, Arberton, et al., 1993) encourages researchers to consider an individual child's and siblings' achievements and their motivation not only as educational outcomes but also as antecedents of the social influences that they receive within the family. In addition, the model calls for attention to be paid to possible effects of other characteristics of the child, such as sex, aptitudes, and personality on parents' beliefs and support. In this section, I review the literature on how the diverse characteristics of an individual child affect parents' beliefs and support.

Effects of Individual Children's Achievement on Parents' Beliefs about Children's Academic Ability

Parents' beliefs are determinants as well as consequences of children's academic achievement (for a review, see Seginer, 1983). Empirical studies have shown that not only do parents' beliefs have an impact on children's academic motivation and achievement (Simpkins et al., 2012; Wigfield et al., 2006), but also, children's academic achievement affects parents' beliefs about children's academic ability (Entwisle & Hayduk, 1981; Okagaki & Divecha, 1993). Yet, investigations of effects of children's achievement on parents' beliefs in prior studies have tended to focus on the formation of parents' general beliefs, which are influenced by children's overall school performance (e.g., Entwisle &

Hayduk, 1981), but they did not address how parents develop child-specific and domain-specific beliefs that are influenced by an individual child's academic achievement in diverse academic domains.

Parents' beliefs about children's ability is domain-specific and child-specific (Eccles, 2007; Wigfield et al., 2015). Accordingly, parental values and behaviors in STEM subjects have affected the extent to which children value the STEM school fields (Šimunović & Babarović, 2020; Šimunović et al., 2018). On the other hand, children's general achievement strategies predicted parents' beliefs about children's general academic ability, whereas children's achievement in the reading domain specifically predicted parents' beliefs about children's reading ability (Aunola et al., 2002). These prior findings have consistently highlighted that the associations between parents' beliefs about children's academic ability and children's achievement are domain-specific. In this regard, it is critical to investigate how children's achievement in diverse academic domains has different effects on the formation of parents' beliefs about children's ability. As numerous empirical studies that have been based on dimensional comparison theory (Marsh et al., 2014; Möller & Marsh, 2013) have shown an association between individual students' achievement and their academic self-concept within and across domains (Möller et al., 2020), it is reasonable to assume that parents would use children's academic achievement as a frame of reference for parents' beliefs about children's academic ability within and across the domains, respectively.

Only recently, a few research studies (Dai, 2002; Van Zanden et al., 2017; Wolff et al., 2020) have drawn from dimensional comparison theory to study parents' domain-specific perceptions about individual children's achievements (Möller & Marsh, 2013). The studies employed the I/E model (Marsh, 1986b) to investigate the combined effect of parents' social/external comparisons of their children's achievement with other students' achievement within academic domains and the effects of parents' dimensional comparisons of their children's achievement in one domain with their children's achievement in another domain on the parents' beliefs about their children's academic abilities. As for social or external comparison effects, when children achieve high grades in an academic domain, both parents and children tend to have higher perceptions of the children's academic capacity in the respective domain (Möller et al., 2020; Van Zanden et al., 2017; Wolff et al., 2020). However, as for dimensional comparison effects on parents' perceptions of children's academic competencies, two studies did not find support for dimensional comparison processes for parents' perceptions of their children's abilities across domains (Dai, 2002; Van Zanden et al., 2017), whereas the other study found support for negative effects of dimensional comparisons on parents' perceptions (Wolff et al., 2020).

Overall, previous studies on effects of dimensional comparisons on parents' domain-specific beliefs have investigated parents' general perceptions in each family by asking either one of the

parents about one of their children (Dai, 2002; Van Zanden et al., 2017) and by aggregating mother's and father's responses to represent the parents' general perceptions about a child in each family (Wolff et al., 2020). Perhaps, such incoherent conceptualizations of the parents' beliefs have resulted in the inconsistent findings of effects of dimensional comparisons on parents' beliefs across studies. Despite the prior studies' novel approach to investigating the formation of domain-specific parental beliefs influenced by individual children's achievements in the math and verbal domains (Marsh et al., 2014; Möller & Marsh, 2013), the studies have yet to address the formation of parents' child-specific beliefs as influenced by individual siblings' achievements within and across academic domains. Given that parents' beliefs are domain-specific but also child-specific (Eccles, 2007; Eccles, Arberton, et al., 1993; Wigfield et al., 2015), the formation of parents' child-specific and domain-specific beliefs about each sibling's academic ability should be investigated further.

Siblings' Achievement as an Additional Frame of Reference for Parents' Child-Specific Beliefs About Ability

Siblings influence one another directly, but they also influence each other indirectly by impacting the family system, particularly their parents (Parke & Buriel, 2007). More specifically, siblings have a substantial influence on parents' expectations about another child's development and parents' behaviors toward another child and provide a referent for parents' differential treatment of their offspring (for a review, see Whiteman, McHale, et al., 2011). Several empirical studies on relationships between parents and siblings have shown that a parent's childrearing experiences with a particular child affected that parent's emotional support for the other child (Spitze et al., 2011) and a parent's conflicts with and knowledge about the other child (Whiteman et al., 2003). In the educational context, a parent's experience with an older child set the parent's expectations for a younger child (Whiteman & Buchanan, 2002). Empirical studies on siblings' influences on parenting have supported a modeling hypothesis (for a review, see Whiteman, McHale, et al., 2011) that siblings serve as a frame of reference for parents' beliefs and support for the other child. Overall, the findings on how siblings influence parents' beliefs and behavior have indicated that the social influence between family members is influenced by each family member and by the family context.

In line with the viewpoints of the sibling modeling hypothesis (Whiteman & Buchanan, 2002), the model of family influences by Eccles, Arberton, et al. (1993) suggests that siblings' characteristics of gender, age, previous academic performance, aptitude, birth order, and achievement motivation (i.e., interests and ability self-concept) affect parents' child-specific beliefs, such as parents' expectations, perceptions of a child's ability, and parents' academic support. Based on the theoretical model (Eccles, Arberton, et al., 1993), it is assumed that not only an individual child's own achievement

but also their sibling's achievement will be used as an additional frame of reference for parents' beliefs about each child's academic ability. The assumed effect of a sibling's achievement on parents' beliefs guides our focus toward a larger family context with more than one child in which siblings have an impact on parents' beliefs and behavior toward an individual child (Furman & Lanthier, 2002).

Siblings are the ideal comparison target because they are close and visible in the family context. In the case of a family with more than two children, parents observe and make comparisons between each child's development (Glascoe & MacLean, 1990). For instance, siblings' academic achievement was found to affect parents' perceptions of each child's academic ability, independent of one individual child's own achievement (Glascoe & MacLean, 1990). In line with the prior finding that showed the influence of siblings on parents' expectations of the other child (Whiteman & Buchanan, 2002), siblings' achievement served as an additional frame of reference for parents' beliefs about the other child's academic ability (Glascoe & MacLean, 1990), supporting the sibling modeling hypothesis (for a review, see Whiteman, McHale, et al., 2011). Considering that parents' beliefs about children's academic ability is domain-specific (Wigfield et al., 2015), and drawing from dimensional comparison theory, siblings' achievements in different academic domains might have diverse impacts on a parent's beliefs about another child's achievement not only within domains but also across domains (Marsh et al., 2014; Möller & Marsh, 2013).

The Reciprocal Effect Between Individual Children's Educational Outcomes and Parents' Support

In the model of family influences proposed by Eccles and colleagues (Eccles, 2007; Eccles et al., 1983), individual children's and siblings' characteristics are assumed to affect parents' beliefs and practices. The theoretical model (Eccles, 2007; Eccles et al., 1983) is in line with the transactional socialization viewpoint (Bell, 1968), which explains that the bidirectional influences between parents and individual children affect individual children's developmental outcomes (Kuczynski & Parkin, 2007; Sameroff, 1994, 2009; Sameroff & Fiese, 1990). The model by Eccles and colleagues (1993) and the transactional socialization viewpoint (Bell, 1968) consistently suggest that the reciprocal association between parents' support and children's motivation should be considered and that the direction of influence is not only from parents' support to children's motivation (Barger et al., 2019; Gonida & Urdan, 2007; Pomerantz et al., 2012; Pomerantz & Moorman, 2010 ; Pomerantz et al., 2007; Pomerantz, Wang, et al., 2005; Urdan et al., 2007) but that children's motivation should also predict parents' support (Salonen et al., 2007).

Recent empirical studies have shown the bidirectional influence between parents' expectations and involvement on the one side and individual children's achievement and motivation on the other (Briley et al., 2014; Dumont et al., 2014; Silinskas & Kikas, 2019a, 2019b). More

specifically, an empirical study reported reciprocal relationships between two dimensions of parental involvement (i.e., academic instruction and socialization) and children's reading achievement from early childhood through adolescence (Sy et al., 2013). Similarly, the reciprocal association between parental homework involvement and children's academic functioning in the reading domain across Grades 5 and 7 was found in an empirical study (Dumont et al., 2014). The findings indicated that parents' support and children's learning motivation mutually reinforced one another.

Due to the bidirectional influence between an individual child and a parent (Kuczynski & Parkin, 2007; Sameroff, 1994, 2009; Sameroff & Fiese, 1990), children in the same family sometimes shape each child's specific learning environment, which contributes to individual siblings' differential educational development (Sy & Schulenberg, 2005). For instance, a study reported that the bidirectional influence between children's learning approaches and achievement and parents' expectations differed between siblings (Briley et al., 2014). This means that a child who has higher motivation and achievement than his/her sibling(s) receives increased parental expectations, and parents' higher expectations of that child over their expectations of the other sibling(s) foster the child's motivation and achievement. In other words, differences between siblings in their academic trajectories reciprocally differentiate parents' beliefs for each of them, which in turn increases the differences in their development. To better understand why siblings differ in their educational development, further studies should be conducted on the diverse dimensions of parents' support and their reciprocal relationships with each sibling's learning motivation.

Effects of Individual Children's and Siblings' Personality, Sex, Birth Order, and Age on Parents' Beliefs and Behavior

For the reciprocal association between children's achievement and motivation on the one side and parents' beliefs and support on the other, it is important to consider potential effects of children's characteristics, such as birth order, sex, aptitude, and temperament, on parent-child interactions according to the model by Eccles and colleagues (1993). Several empirical studies have shown substantial effects of children's sex, birth order, and personality on differentiated parental beliefs and behavior with respect to siblings.

Effects of Sex on Parents' Beliefs and Behavior. A few empirical studies have focused on how the interplay of children's and parents' biological sex differentiate parents' beliefs about children's academic abilities, independent of children's own academic achievement level. For instance, although there was no significant difference between female and male students' school grades, both mothers and fathers tended to be more satisfied with their daughters' school grades than with their sons' school grades (McGrath & Repetti, 2000). In addition, individual children's sex was especially strongly

related to parents' child-specific beliefs about children's ability in science, technology, engineering, and mathematics (STEM), which, in turn, had an impact on students' achievement motivation, performance, and career choices related to STEM domains (Šimunović & Babarović, 2020). Children's and siblings' sex also had an influence on parents' behaviors. Specifically, males whose closest sibling was female perceived their parents as more punitive (Kidwell, 1981). Taken together, the previous empirical findings showed how parents' gender stereotypes have an impact on parents' child-specific ability beliefs as well as parents' behaviors as hypothesized by Eccles and colleagues (1993).

Birth Order Effects on Parents' Beliefs and Support. In addition, children's birth order was hypothesized to have an impact on parents' beliefs and support (Eccles, Arberton, et al., 1993). For instance, higher parental achievement expectations were reported for first-born than for later-born children (Ernst & Angst, 1983), and thereby, higher demands were placed on first-born than on later-born students (Ernst & Angst, 1983), and parents tend to impose stricter responses to their earlier-born children's poor performance in order to deter younger ones from pursuing such outcomes (Hotz & Pantano, 2015). Similarly, sibling status (i.e., birth order) was found to have a substantial influence on parents' perceptions of their own children (Musun-Miller, 1993). In addition, an empirical study reported a significant interaction between children's gender and birth order on children's perceptions of parents' rearing behavior (Someya et al., 2000). More specifically, earlier-born male children tended to experience parental rejection more than others, whereas earlier- and later-born female children were more likely to perceive their parents as warm and caring than others (Someya et al., 2000). If the findings are incorporated, birth order has an impact on parents' perceptions (Musun-Miller, 1993) and their educational expectations (Musun-Miller, 1993) of each sibling, which further affect how they treat the siblings differently (Hotz & Pantano, 2015; Someya et al., 2000).

Effects of Children's Personality on Parents' Support. According to a process model of parenting proposed by Belsky (1984), the personality traits of parents and children along with contextual factors were postulated to have an impact on parents' functioning. Accordingly, in the review of the relevant literature on the process model, parents who are low in neuroticism and high in extraversion, agreeableness, openness to experience, and conscientiousness were likely to foster children's development (Belsky & Barends, 2002). Parents with such personality traits tended to be supportive and intellectually stimulating regardless of their children's ages (Belsky & Barends, 2002). Accordingly, parental personality has been emphasized as a way to differentiate across parenting styles (Browne et al., 2012; Vondra et al., 2005) as well as a factor that can predict children's development (Belsky & Barends, 2002).

On the other hand, the model of family influences by Eccles and colleagues (1993) hypothesized effects of children's temperament and aptitude on parents' beliefs and behaviors. In contrast to the prior theories, which highlighted parents' personality for its strong association with the parent-child relationship (Belsky, 1984), an empirical finding showed that there was no association between parents' personality and the parent-child relationship, whereas children's personality showed the most consistent associations with the parent-child relationship (Werneck et al., 2014). Accordingly, other studies have also found positive associations between children's conscientiousness and extraversion and parents' social-conformity-related socialization values (Tamm et al., 2021) as well as between children's agreeableness and conscientiousness on the one side and parents' sense of parental accomplishment and low emotional exhaustion and distancing on the other (Vigouroux & Scola, 2018). However, children's neuroticism was negatively associated with parents' sense of accomplishment but positively associated with parents' emotional exhaustion and distancing (Vigouroux & Scola, 2018). Taken together, these results demonstrate the importance of considering the personality of both parents and children in the study of parental values and support and the parent-child relationship.

1.4. Effects of Sibling Resemblance

In the earlier sections, I reviewed the relevant literature on expectancy-value theory's model of family influences (Eccles, Arberton, et al., 1993). Overall, the reviewed theories and empirical findings highlighted that not only do parents' child-specific beliefs and behaviors have an impact on children's educational outcomes, but also, individual children's achievement and motivation, along with the characteristics of sex, birth order, and personality, reciprocally affect parents' beliefs and behaviors for each sibling and their own achievement motivation. The reviewed studies have consistently addressed how the characteristics of individual children and their siblings act to diversify the influence of parents and educational outcomes between siblings.

Regarding the effects of individual children's characteristics on diversifying parents' child-specific beliefs, support, and children's academic self-concepts, another important question to ask is what happens when siblings are very similar to each other? Theoretically, if each child's differential characteristics are assumed to diversify parents' beliefs and behaviors with respect to each sibling, when siblings have similar characteristics, this should promote similar perceptions and similar behaviors in parents toward each sibling. This means that parents are likely to compare siblings' characteristics for similarities and differences, which should further affect parents' child-specific beliefs and how parents treat siblings. In this regard, sibling resemblance might be a potential moderator of academic socialization between parents and children. Additionally, sibling resemblance should impact how siblings perceive and interact with each other because interpersonal similarity is assumed to have an influence on how individuals socially contrast or assimilate to one another according to social comparison theory (Festinger, 1954). Based on the perspective of social comparison theory (Abrams & Hogg, 1990; Hogg & Turner, 1987; Jetten et al., 1996), sibling resemblance might moderate effects of siblings' comparison processes on their deidentification or assimilation (Whiteman, Bernard, et al., 2011). From these viewpoints, family members' perceptions and comparisons of similarities/differences in siblings' characteristics are assumed to affect academic socialization within the family. The perspective of sibling resemblance effects extends our focus from individual child-level characteristics to sibling-level characteristics, such as age spacing, the pattern of biological sex across siblings, and overall similarities.

In this section, I will review the relevant literature on effects of sibling resemblance on academic socialization within the family from the social comparison theory perspective (Festinger, 1954).

Social Comparison Theory

Social comparison theory (Festinger, 1954) explains individuals' intrinsic tendency to evaluate themselves on the basis of how they perceive others, especially those whom they perceive as similar and close to themselves. According to the theory, when individuals perceive similarity and closeness with others, they tend to make a favorable comparison, and the close other's achievement thus reflects positively on their self-concept (Clement & Krueger, 2002; Jetten et al., 2001). Accordingly, similar individuals tend to strongly associate themselves with one another, and thereby, they often show an assimilation effect among themselves (Abrams & Hogg, 1990; Hogg & Turner, 1987; Jetten et al., 1996). On the other hand, if individuals perceive dissimilarity with others, they tend to deidentify themselves with the comparison targets or comparison groups, and thereby, comparisons with dissimilar others usually have a contrast effect on their self-concept (Abrams & Hogg, 1990; Hogg & Turner, 1987; Jetten et al., 1996). Therefore, the perceived similarity and closeness of the relationship and the relevance of the domain have been identified as moderators of the effects of social comparison on self-concept in the experimental setting (Dijkstra et al., 2008; Mussweiler, 2003; Thomas Mussweiler et al., 2004).

In line with social comparison theory (Festinger, 1954), several theoretical models and empirical studies have also stressed stronger effects of concrete comparisons with close friends, classmates, and family members in the immediate environment on individuals' self-concept and self-evaluations (Alicke et al., 2009; Festinger, 1954; Suls et al., 2000; Zell & Alicke, 2010; Zell et al., 2017). Given that comparison processes are assumed to be strong in the family due to the proximity of the context (Zell & Alicke, 2010), the active comparison of similarities and differences across siblings are assumed by parents and between siblings. From the perspective of social comparison theory (Festinger, 1954), as for the similar siblings, parents may associate a child's characteristics with another child's characteristics and treat them similarly. As for dissimilar siblings, parents are less likely to associate one child with the other child and interact with them in different ways. Accordingly, favorable comparison processes are assumed between similar siblings, whereas a social contrast effect is assumed between dissimilar siblings, which would further impact the self-concept formation of an individual child. On the basis of these expectations, it would be reasonable to investigate sibling resemblance as a potential moderator of academic socialization within the family.

Effects of Sibling Resemblance on Siblings' Interactions

As described earlier in Chapter 2.2., depending on the perception of another sibling as either a comparison target or a model for learning, siblings' relative achievements had either a negative (We & Park, 2011) or positive (Bandura, 1977) effect on another sibling's academic self-concept in the learning situation. From a social comparison theory perspective (Festinger, 1954), the social

comparison of sibling similarity may be relevant to sibling dynamics. Based on social comparison theory (Festinger, 1954) and the relevant empirical findings (Clement & Krueger, 2002; Jetten et al., 2001), it can be hypothesized that very similar and close siblings are more likely to show social learning effects, whereas dissimilar siblings are more likely to show social contrast effects and sibling nonreferencing regarding their relative achievements or failures (Whiteman, McHale, et al., 2011). In other words, the perceived similarity between siblings should moderate effects of siblings' social learning and social contrasts on their academic self-concept formation. A review of sibling relationships and interactions has accordingly highlighted the perceived similarity between siblings as a powerful influence on how they mutually influence one another throughout life (Her et al., 2021).

Several different areas of the literature on siblings are consistent with the expected effects of sibling resemblance on their interaction. For instance, same-sex siblings are more likely to view each other as models for social learning (Koch, 1956; Sutton-Smith & Rosenberg, 1970) and are likely to show higher levels of intimacy and less hostility (Oliva & Arranz, 2005) than siblings of the other sex. Similar findings have also shown that adult siblings' similarities in gender, age, educational level, and partner status had a small but favorable effect on supportive behaviors within female-sibling pairs (Voorpostel et al., 2007). These findings imply that similarities between siblings in sex and other characteristics foster siblings' social learning and a favorable relationship. The findings are in line with the hypothesis from social comparison theory (Festinger, 1954) that perceived interpersonal similarity has an impact on assimilation and closeness in the relationship.

Effects of Sibling Resemblance on Twins' Interactions

With regard to effects of sibling resemblance, it is helpful to focus on twin pairs because they are so similar to each other. As twins grow, they constantly and mutually compare themselves with each other because they are so physically and emotionally close and are in the same developmental phase (Fortuna et al., 2010). Interestingly, MZ and DZ twins differ not only in the extents to which their genetics and characteristics are similar but also in their socialization with their co-twin (for a Meta-analysis see, McCartney et al., 1990).

Whereas MZ twins are genetically identical, DZ twins share approximately 50% of their genes and are thus as different as any other nontwin siblings (Reiss & Leve, 2007). Accordingly, a within-pair correlational analysis showed that MZ twins are more similar to each other than DZ twins are (Reiss, 2003). Empirical findings have also shown that MZ and DZ twins perceive their similarity and differences to different degrees (Watzlawik, 2009). In this regard, MZ and DZ twin data can be used to compare very similar siblings and less similar siblings, respectively, to investigate how interpersonal similarity moderates the comparison processes among family members.

Compared with DZ twins, MZ twins are more likely to depend on (Penninkilampi-Kerola et al., 2005) and to be attached to (Fraley & Tancredy, 2012) their co-twins and are therefore less competitive and more cooperative with each other (Segal & Hershberger, 1999; Segal & Knafo-Noam, 2018). The empirical evidence for differences in MZ and DZ twins' socialization with their co-twins highlights interpersonal similarity as an important moderator of the relationship and the social comparison within twin pairs as hypothesized in social comparison theory (Festinger, 1954). In this regard, the effect of a co-twin's achievement on a target twin's academic self-concept might differ between MZ and DZ twins as they feel different degrees of similarity and socialize differently with their co-twin.

Effects of Sibling Similarity on Parents' Beliefs and Support

Given that sibling characteristics, along with individual children's characteristics, are assumed to affect how parents adjust their parental support and behavior for each child (Eccles, 2007; Eccles, Arberton, et al., 1993), similarities and differences in siblings' characteristics would affect parenting, such that parents tend to treat similar siblings more similarly. In several empirical studies, the perceived resemblance among family members played a role in differentiating parental influences for siblings. The perceived resemblance between a parent and a child predicted the parent's investment in more time, money, and care in their children (Apicella & Marlowe, 2004; Dolinska, 2013) and resulted in reports of higher emotional closeness (Alvergne et al., 2010). An empirical finding also showed that mothers substantially made judgements of the differences across siblings (Schachter et al., 1978). In this regard, parents' beliefs and support are likely to differ by sibling resemblance.

Twin studies have examined how different types of twins, namely, MZ and DZ twins, experience their parents' support to different degrees (Plomin & Bergeman, 1991). Parents tend to perceive MZ twins as more similar than DZ twins. For instance, the cross-correlations of a mother's negative perception of one child with another child's antisocial behavior was .62 for MZ twins, .27 for DZ twins, and .29 for nontwin siblings (Reiss, 2003). The findings showed that parents tended to perceive MZ twins as more similar than DZ twins or nontwin siblings. Accordingly, an empirical studied found that MZ twins were more likely to be treated similarly by parents than DZ twins. The studies using children's responses reported that MZ twins were treated more similarly by their parents than DZ twins were (Lytton, 1977; Morris-Yates et al., 1990; Rowe, 1981). More specifically, parents were perceived to treat MZ twins more similarly than DZ twins even when they were mistaken about the twin's zygosity (e.g., Actual MZ twins were believed to be DZ twins by parents and vice versa; Lytton, 1977). The other study also reported that parents' knowledge of zygosity did not affect how the parents treated the children (Cohen et al., 1977). This implies that parents did not introduce

systematically greater similarity in their treatment of MZ twins than DZ twins due to their expectations of similarity based on their knowledge of zygosity, but they responded to the resemblance between the twins (Lytton, 1977). Another study comparing MZ and DZ twins also consistently showed that environmental influences were responsible for the effect of sibling resemblance on twins' perceptions of parents' behaviors, except for the father's interactions with the twins (Rowe, 1981). The finding that parents reacted to MZ twins in more similar ways than they did to DZ twins (Furman & Lanthier, 2002) indicates that perceived sibling similarity had an impact on how parents associate a child with their sibling and how parents accommodate their actions to the child's individuality and needs, consistent with what has been hypothesized in social comparison theory (Festinger, 1954). Accordingly, it is reasonable to assume that sibling resemblance should also have an impact on how parents perceive and treat siblings.

2. Research Aims and Hypotheses

Overall, the current dissertation is aimed at providing theoretical and empirical support for the model of family influences on children's motivation and achievement proposed by Eccles and colleagues (Eccles, 2007; Eccles, Arberton, et al., 1993). Yet, the dissertation focuses on the hypothesized effects of individual children's and siblings' characteristic on academic socialization within the family, topics that were given only a little attention in the reviews of the relevant literature on the theoretical model (Eccles, 2007; Wigfield et al., 2015). However, the limited prior research reviewed in the current dissertation suggested that effects of children's characteristics represent a fruitful direction for research on academic socialization within the family. Drawing from the theoretical model proposed by Eccles and colleagues (Eccles, Arberton, et al., 1993) and the relevant literature, the current dissertation contains four hypotheses.

First, we hypothesized that each child would have individual experiences in the family and that siblings would also share experiences in the family. As for each child's individual experiences in the family, parents' ability beliefs and support for learning are expected to be child-specific. As for siblings' shared experiences in the family, parents are also expected to have general beliefs and general support for siblings in the family. Thus, the dissertation is aimed at providing empirical evidence for both a child-specific learning environment and a shared learning environment across siblings within the family.

Second, we hypothesized that each individual child's characteristics would have effects on their own educational outcomes. According to the model of family influences (Eccles, Arberton, et al., 1993) and the I/E model (Marsh, 1986b), individual children's academic achievement is expected to affect their own academic self-concept as well as their siblings' academic self-concept within and across academic domains. By providing empirical support for the hypotheses, we aimed to show that each child is an active agent of their own academic self-concept in the contexts of both school and home.

Third, we hypothesized that individual children's characteristics would have an effect on their parents. Specifically, individual children's achievement and their learning motivation are expected to be antecedents of parents' beliefs and practices. Grounded in the model of family influences (Eccles, Arberton, et al., 1993) and the I/E model (Marsh, 1986b), individual children's achievement is expected to affect their parents' child-specific ability beliefs within and across the math and verbal domains. For families with more than one child, we expected that each individual child's achievement would further affect parents' beliefs about the child's and sibling's academic ability as sibling's achievement can be observed in the family context. On the other hand, based on the viewpoint of the

transactional model (Kuczynski & Parkin, 2007; Sameroff, 2009), an individual child's learning motivation is assumed to have a reciprocal relationship with diverse dimensions of parents' support. Yet, the reciprocal relationship is expected to differ between siblings as siblings are expected to differ in their levels of learning motivation and other characteristics, such as school grades, sex, and personality.

Fourth, we hypothesized that sibling resemblance would have effects on siblings' comparison processes and parents' perceptions and support of siblings. According to social comparison theory (Festinger, 1954), sibling resemblance is expected to foster sibling assimilation as well as similar parental support for siblings. To be more specific, when siblings are very similar to one another, a child's achievement is expected to positively affect their sibling's academic self-concept due to the expected level of assimilation. In the case of dissimilar siblings, a child's achievement is less likely to affect or will negatively affect their sibling's academic self-concept due to the assumed social contrast. In addition, on the basis of previous empirical findings (Reiss, 2003), parents are expected to provide similar support for very similar siblings, whereas parents are expected to give different support to dissimilar siblings.

To address the four hypotheses, we conducted three empirical studies to investigate dynamic intrafamilial influences within the family. The first study focused on parents' beliefs about academic ability and investigated the extent to which parents' beliefs differed according to the diverse levels of influence within the family. By employing the I/E model (Marsh, 1986), the study further investigated how an individual child's and their sibling's achievement affected their mother's and father's beliefs about the child's academic ability within and across domains. The second study focused on the reciprocal relationships between diverse dimensions of parental support (i.e., parents' expectations, parents' emotional support, parents' learning encouragement, and parental control) and an individual child's learning motivation and investigated whether the reciprocal associations differed between siblings. By analyzing the reciprocal associations separately for MZ and DZ twins, the study determined whether the reciprocal effects differed between MZ and DZ twins regarding the relative resemblance between siblings. The third study investigated whether a co-twin's achievement affected a target twin's academic self-concept within and across domains based on the I/E model. By comparing MZ and DZ twins, the study further examined whether the effects of a co-twin's achievement on a target twin's academic self-concept differed between MZ and DZ twins as they are assumed to differ in their comparison processes on the basis of social comparison theory (Festinger, 1954). To address our hypotheses, we used family design data and applied statistical models that could represent complex interactions within the family. To this end, I hereby present the three empirical studies.

3. Study 1: Sibling Achievement as an Additional Frame of Reference for Parents' Beliefs About Each Child's Academic Ability

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Abstract

Expectancy-value theory and the family socialization model (Eccles, 2007) suggest that parents hold beliefs about each child's academic ability, and parents construct their beliefs by collecting information about their children's academic ability, such as about a child's—and a sibling's—prior achievements. Accordingly, we investigated whether parents hold child-specific beliefs about each sibling's academic achievement and how much the beliefs differ between siblings. Then, we applied Marsh's (1986) internal/external frame of reference (I/E) model to investigate whether parents construct their beliefs on the basis of an individual child's and their sibling's academic achievement within and across domains. For the analyses, we used secondary data from 95 families with two children collected in two academic-track secondary schools in a rural area of Germany. The data included each mother's and father's responses about each child and each individual sibling's achievements in math and German. The results showed that parents' beliefs about their children's academic abilities differed between siblings. In addition, each parent constructed their beliefs about each child's academic ability on the basis of not only the child's own achievements but also the sibling's achievements within and between domains. Although we could not observe the consistent pattern suggested by the I/E model on the formation of parents' beliefs, we found tentative empirical evidence that each child's and their sibling's achievement simultaneously affected parents' beliefs about an individual child's academic ability within and across academic domains in line with the I/E model (Marsh, 1986) and the family socialization model's viewpoint (Eccles, 2007).

Sibling Achievement as an Additional Frame of Reference for Parents' Beliefs About Each Child's Academic Ability

Parents' perceptions of children's academic abilities are of critical importance, particularly because they are likely to have an impact not only on the parents' behaviors but also on the children's educational motivation and outcomes (Eccles, 2007; Eccles, Arberton, et al., 1993; Gladstone et al., 2018; Miller, 1988). Educational researchers have studied how parents' beliefs are influenced by sociocultural factors outside the family, such as socioeconomic status and cultural background (for a review, see Kotchick & Forehand, 2002). However, very few empirical studies in education have looked closely at how parents adapt their beliefs to diverse intrafamilial influences.

Parents construct their beliefs on the basis of an individual child's characteristics, such as gender, aptitude, birth order, and academic performance (Eccles, 2007). Accordingly, each parent constructs child-specific beliefs and makes choices about academic support, homework help, and discipline for each child (Gonida & Cortina, 2014). On the other hand, not only do an individual child's characteristics but also their siblings' characteristics contribute to parents' child-specific beliefs (Eccles, 2007) because parents collect information on each child's development by comparing differences between siblings in the family context (Glascoe & MacLean, 1990). Taken together, on the basis of the perspective of expectancy-value theory's model of family influences, we hypothesized that individual children's traits and their siblings' traits jointly influence parents' beliefs about each child.

To provide empirical evidence of what has been hypothesized in the model of family influences, we used secondary data collected from 95 families with two children in two academic-track secondary schools in Germany. The data included each parent's responses regarding their beliefs about each older and younger child's academic ability and the children's math and German grades. Thereby, the data were suitable for addressing our research questions. We investigated whether each parent held child-specific beliefs about each child's academic ability and the extent to which parents' beliefs differed between siblings. Then we further examined how each parent constructed their perceptions of each individual sibling's academic ability. Specifically, we investigate how an individual child's own achievements and their sibling's achievements within and across academic domains affected parents' beliefs about each child in the family concerning previously reported social and dimensional comparison effects on parents' beliefs (Möller & Marsh, 2013; Möller et al., 2020; Wolff et al., 2020). Overall, we aimed to provide a "snapshot" of the diverse frames of reference used for each mother's and father's perceptions of each older and younger child's academic abilities.

Effects of Social and Dimensional Comparisons on Parents' Perceptions of Children's Competence

Each parent can develop their perceptions about each child's academic abilities by evaluating any information they receive about each child's achievements in the context of the larger family, including when siblings using diverse comparisons processes, such as social comparisons (Festinger, 1954), dimensional comparisons (Möller & Marsh, 2013), or temporal comparisons (i.e., changes in achievement; Wolff et al., 2020). Thus, each parent makes reference to each child's academic achievement throughout diverse comparison processes to construct their beliefs about their children's academic abilities.

There are several empirical studies that have investigated effects of social and dimensional comparisons on parents' beliefs about children's academic abilities. The studies employed the I/E model (Marsh, 1986b) to investigate the combined effect of parents' social/external comparisons of their children's achievement with other students' achievement and the effect of parents' dimensional comparisons of their children's achievement in one domain with their children's achievement in another domain on parents' beliefs about children's academic abilities. For social or external comparison effects, when children get good grades in an academic domain, both parents and children tend to have higher perceptions about the children's academic capacity in the respective domain (Möller et al., 2020; Van Zanden et al., 2017; Wolff et al., 2020).

Only recently, a few empirical studies based on dimensional comparison theory (Möller & Marsh, 2013) have focused on whether parents compare their children's achievements in math with achievements in the verbal domain for their beliefs about their children's academic abilities. However, the studies presented inconsistent results on parents' use of dimensional comparisons for their perceptions of their children's academic competencies. Two studies did not find support for dimensional comparison processes for parents' perceptions of children's ability across domains (Dai, 2002; Van Zanden et al., 2017), whereas the other study found support for the negative effect of dimensional comparisons for parents' perceptions (Wolff et al., 2020). Overall, previous studies on parents' dimensional comparisons investigated parents' general perceptions in each family by asking either one of the parents about one of their children. When both the mother and father responded in a survey, their responses were averaged to represent parents' general perceptions (Wolff et al., 2020). Subsequently, the prior findings addressed the social and dimensional comparison processes for parents' beliefs about children's competence by comparing one family with another. Therefore, a parent's specific beliefs about each sibling's academic ability and parents' social and dimensional comparison processes within the family have yet to be addressed.

Siblings' Achievement as a Frame of Reference for Parents' Child-Specific Ability Beliefs

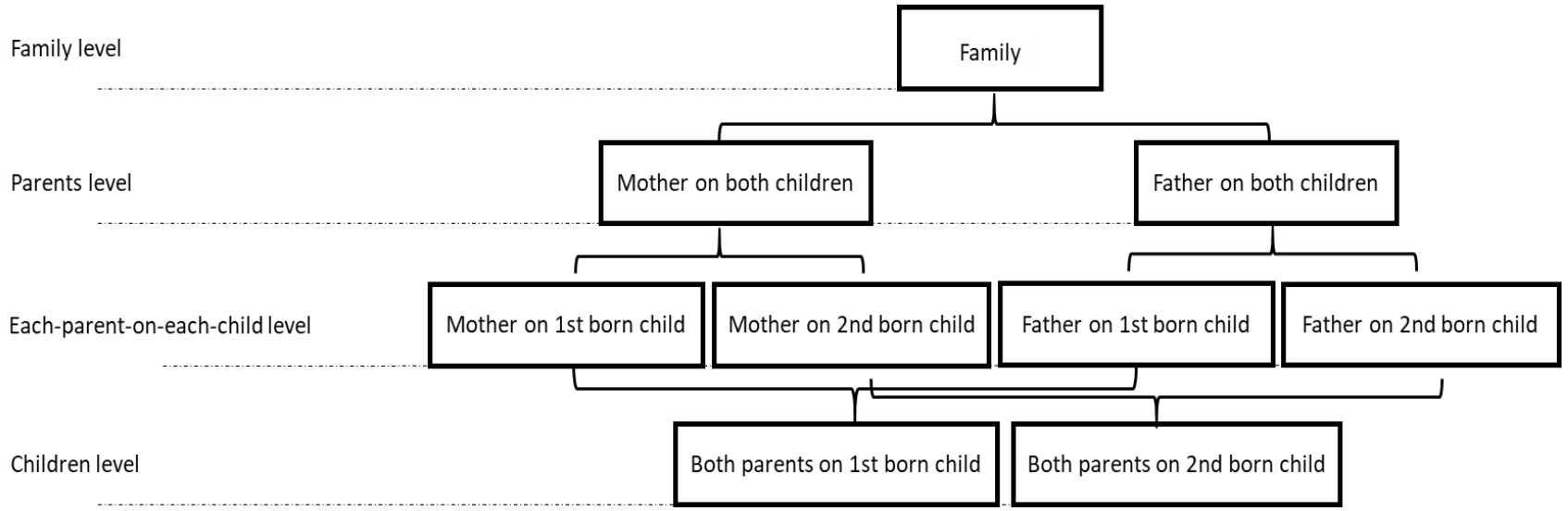
Parents hold not only general perceptions of their children but also specific perceptions and beliefs about each child in the family. Expectancy-value theory's model of family influences (Eccles, 2007; Eccles, Arberton, et al., 1993) provides a framework that is useful for understanding how parents form child-specific beliefs. Specifically, parents' characteristics, such as education level, socioeconomic status, gender, general beliefs (i.e., gender-role stereotypes, efficacy beliefs, and values) along with an individual child's and sibling's characteristics, such as gender, age, previous academic performance, aptitude, birth order, and achievement motivation (i.e., interests and ability self-concept) form a parent's child-specific beliefs, such as parents' expectations, perceptions of a child's ability, and academic support (Eccles, 2007). Based on expectancy-value theory, it is reasonable to speculate that not only an individual child's own achievement but also a sibling's achievement will be used as a frame of reference for each parent's beliefs about each child's academic ability.

Siblings are ideal comparison targets as they are close and visible in the family context, and thereby, an older sibling's school achievement may affect the school outcomes of a younger sibling (Nicoletti & Rabe, 2019). Accordingly, in the case of a family with more than two children, parents make comparisons between their children for information about each child's development (Glascoe & MacLean, 1990). Specifically, siblings' academic achievement, independent of an individual child's own achievement, were found to affect parents' perceptions of the child's academic ability (Glascoe & MacLean, 1990). Siblings' achievement should therefore contribute to parents' perceptions of another child's academic ability. Specifically, effects of siblings' achievements contribute to diversifying parents' child-specific perceptions of their children's abilities, as each sibling differs in their individual characteristics and achieves differently (Cicirelli, 1978; Lindert, 1977).

To the best of our knowledge, researchers have not yet examined effects of siblings' achievements on parents' beliefs about the other child's academic ability by applying the I/E model. As outlined earlier, there is robust empirical evidence of the joint effect of dimensional and social comparison effects on individuals' perceptions of their own academic ability (Möller et al., 2020) and for parents' perceptions of children's academic ability in a recent study (Wolff et al., 2020). In addition, parents were found to use siblings' achievement for their perceptions of another child's academic ability, independent of the child's own achievement (Glascoe & MacLean, 1990). On the basis of these findings of effects of social and dimensional comparisons on parents' beliefs, we carefully speculated that we would further observe that parents use a sibling's achievement as a frame of reference for their perceptions of another child's academic ability within and across academic domains.

Figure 1

Data Level Structure



The Present Study

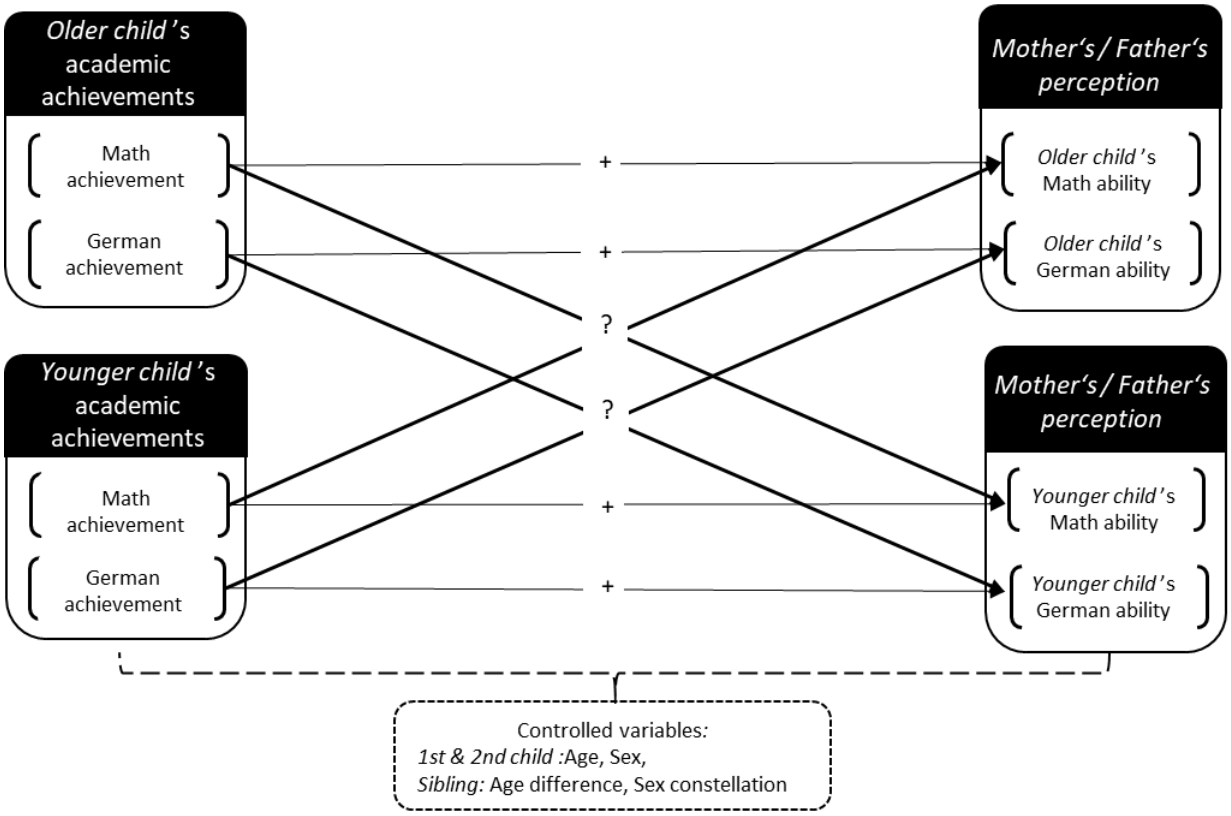
To this end, we used data from 95 families with two children in two academic-track secondary schools in a rural area of Germany. Despite the small sample size, the data were rich in quality and were well-suited for addressing our complex research questions. The data included the responses of each parent's perceptions of each child's academic capacity in two different subjects—math and German—and each sibling's math and German grades.

The present study had three major aims and hypotheses. First, we aimed to provide empirical evidence of parents' perceptions of specific children's academic ability in comparison with parents' general perceptions of siblings' academic abilities. Specifically, we were interested in the extent to which each parent's perceptions of each child's ability differed between siblings in comparison with the extent to which parents' general perceptions of siblings' academic abilities differed across families. Accordingly, we conducted a multilevel analysis of parents' perceptions of children's math and German abilities and decomposed the variances at four levels: (a) family, (b) parents, (c) individual parent on individual child, and (d) children in the random intercept model (see Figure 1). On the basis of expectancy-value theory's model of family influences, we expected that we would observe substantial variance at the level of the responses of each individual parent on each individual child as an indicator of parents' child-specific perceptions and the variances at other levels as indicators of parents' shared perceptions of siblings (Eccles, 2007; Eccles, Arberton, et al., 1993).

Second, we aimed to further investigate whether parents would use an individual child's achievement and their sibling's achievement as frames of reference for their perceptions of each sibling's academic ability in the math and German domains. To do this, we tested the parallel effects of each older and younger child's achievement with each mother's and father's ratings of each older and younger child's competencies as dependent variables (see Figure 2). For instance, we investigated whether a child's and their sibling's math achievement (i.e., two independent variables) would predict the mother's beliefs about the child's math ability. We ran regression models for math and German separately. On the basis of previous empirical findings, we expected to find significant effects of individual children's achievement as well as their siblings' achievement on mothers' and fathers' perceptions of each child's own academic ability in the respective domain (Glascoe & MacLean, 1990).

Figure 2

Social Comparison- and Sibling Achievement Effects on Each Parent's Perceptions of Each Older and Younger Child's Academic Abilities

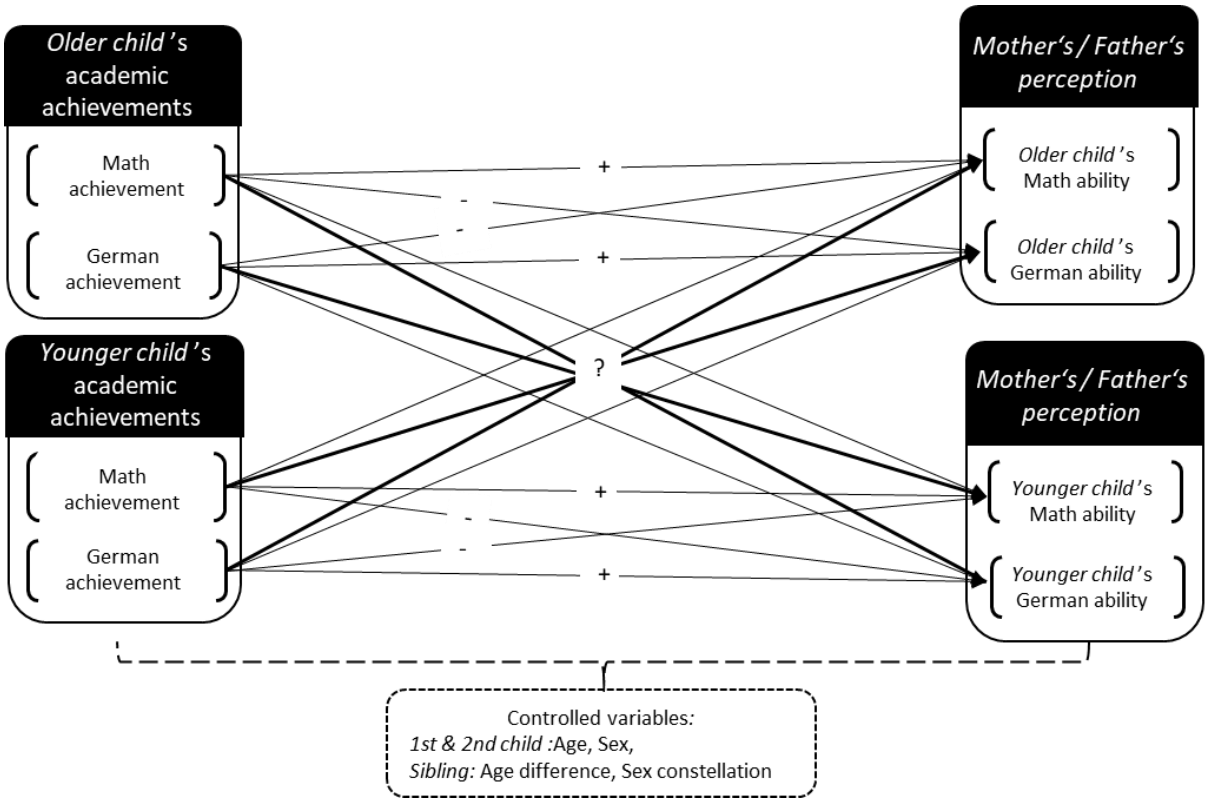


Note. Bold lines indicate sibling achievement effects on parental perception of the other child's academic ability in the respective domains

Third, we aimed to extend prior studies on social and dimensional comparison effects on parents' beliefs (Dai, 2002; Van Zanden et al., 2017; Wolff et al., 2020) by shifting the focus to the within-family level. Specifically, we investigated whether parents use a sibling's achievement as an additional frame of reference for their perceptions of the other child's academic ability within and across domains with respect to dimensional comparison effects (see Figure 3). In other words, when a parent evaluates each child's academic ability in a certain subject, we aimed to determine whether the parent bases their evaluation on the individual child's own achievement and the sibling's achievement in that subject and another subject. For instance, we tested whether a child's and a sibling's achievements in math and German (i.e., four independent variables) would predict the mother's beliefs about the child's math ability.

Figure 3.

Parental Dimensional Comparisons of Siblings' Achievements for Their Beliefs About Each Other Child's Academic Abilities



Note. Bold lines indicate the effects of siblings' achievements on parental perception of the other child's academic ability across the domains.

For all regression analyses aimed at addressing the second and third research questions, we controlled for an individual child's characteristics of biological sex and age and the siblings' sex constellation and their age difference as these variables have been found to be related to parents' perceptions of children's academic ability (for a review, see Cicirelli, 1978).

Method

Data

We reanalyzed data collected from two academic track schools in Baden-Württemberg, Germany. Thus, the data were quite selective in nature. We focused on a subsample from a previously published study of 830 students and their parents by Gladstone et al. (2018), for which we selected data from 95 families with two children in Grades 5 to 12. As we only included families with two children, eight families with more than two children or with twins were excluded from our analyses. Each parent was asked specifically about each sibling in separate questionnaires.

Excluding three missing responses on all key variables, we had a subsample of data from 92 mothers and fathers with data on an earlier-born child (*N* = 92) and a later-born child (*N* = 91) out of 95 families. Yet, because we included auxiliary variables when data were missing on the key measures, we analyzed a total of 94 families in our main analyses. The older children's age ranged from 11 to 18, and the younger children's age ranged from 9 to 16. For the age difference, there were 32 pairs of siblings with an age gap of less than 2 years, 30 pairs of siblings with an age gap between 2 to 3 years, and 19 pairs of siblings with an age gap of more than 3 years. The older child consisted of 44 females and 48 males, and the younger child consisted of 49 females and 42 males. There were 48 pairs of same-sex siblings (female siblings: *N* = 25; male siblings: *N* = 23), and there were 43 pairs of different-sex siblings.

Measures

For control variables, we used children's biological sex, children's age, siblings' age difference, and siblings' sex constellation as additional covariates in our analysis. Individual children's sex was coded 0 for female and 1 for male. For siblings' age difference, we created a dummy variable to indicate 1 for sibling pairs with less than a 2-year age difference and 0 for sibling pairs with more than a 2-year age gap. For siblings' sex constellation, we also created a dummy variable to indicate 1 for same-sex siblings and 0 for different-sex siblings.

For independent variables, we used the older- and younger children's school grades in math and German achieved in the previous year. When a report of the official school grade was missing (19.0%), we used students' self-reported grades. With regard to the validity of using self-reported grades, previous studies have shown a strong association between reported and actual grades across domains and grade levels (Dickhäuser & Plenter, 2005a; Sticca et al., 2017). As the school grades are assigned on a scale ranging from 1 (*very good*) to 6 (insufficient) in Germany, we recoded the school grades so that higher values indicated higher achievement for ease of interpretation. On average, we had information about grades for 96.8% of the older children and 90.5% of the younger children.

For dependent variables, each parent's report of their perceptions of each child's abilities in math and German consisted of three items. The items included "My child is good in math/German," "Compared with other children, my child has a natural talent in math/German," and "I think my child is successful in math/German in this school year." The answers ranged from 1 (*do not agree*) to 5 (*fully agree*). The internal consistency of the scales ranged from α = .83 to α = .93 for mothers' and fathers' beliefs across the older- and younger children's math ability, and it ranged from α = .79 to α = .86 for mothers' and fathers' beliefs across the older- and younger children's German ability. However, the missing data rate ranged from approximately 22.1% to 25.3% for mothers' perceptions of the older- and younger children's math and German abilities, and it was overall 24.2% for fathers' perceptions.

We managed the missing data (see Table 1 for proportions of missing data) with full information maximum likelihood estimation, which uses all available information based on the missing-at-random assumption (Baraldi & Enders, 2010; Graham, 2009). To make the missing-at-random assumption more plausible, we included whether parents had an immigration background, each older- and younger child's personality (i.e., conscientiousness), and each child's math and German self-concept as auxiliary variables in our analyses. To avoid bias, we carefully selected variables that were related either to parents' perceptions or to missingness in the parental perception data based on correlation analyses and theoretical considerations (Graham, 2003; Thoemmes & Rose, 2014; van Buuren et al., 1999).

Statistical Analyses

For the first research question specifically, the data were organized into four levels: family, parents, each parent's response on each child, and children, respectively (see Figure 1). We decomposed the variance in parents' perceptions of their children's abilities in math and German by running random intercept models in which each child-specific response from each parent was nested within children, parents, and families.

For the second research question, we ran a multivariate regression model in Mplus (Muthen et al., 2017). We regressed each mother's and each father's perceptions of each older- and younger child's ability on each child's and sibling's achievements in the respective domain (see Figure 2). We added children's age, children's biological sex, siblings' age difference, and siblings' sex constellation as covariates. We ran the model separately for mothers and fathers but integrated them into a regression model. We ran two regression models, one for math and one for German. Consequently, each regression model for math and German included two independent variables, consisting of both the older- and younger child's achievements; four dependent variables, consisting of each mother's and each father's perceptions of each older- and younger child's academic ability; and four control variables, consisting of children's age, children's biological sex, siblings' age difference, and siblings' sex constellation.

For the third research question, we added each older- and younger child's achievement in nonmatching domains to the abovementioned regression models for math and German (see Figure 3). Consequently, we regressed each mother's and each father's perceptions of each older- and younger child's ability on both children's achievement in matching and nonmatching domains with the additional covariates of children's age, children's biological sex, siblings' age difference, and siblings' sex constellation. We ran separate regression models for math and German but integrated them into one regression model. Consequently, we analyzed the effects of four independent variables, consisting of each older- and younger child's math and German ability, on eight dependent variables,

consisting of each mother's and each father's perceptions of each child's ability in math and German, while accounting for the four covariates, consisting of children's biological sex, children's age, siblings' age difference, and siblings' sex constellation.

Table 1

Descriptive Statistics

	M	*SD*	*N*	Missing *N*	Ratio	1	2	3	4	5	6	7	8	9	10	11
1. Older child's math grade	3.61	0.95	92	3	3.2	1										
2. Older child's German grade	2.87	0.77	92	3	3.2	.13	1									
3. Younger child's math grade	3.63	0.88	86	9	9.5	.22	.13	1								
4. Younger child's German grade	2.99	0.77	86	9	9.5	.21	.31	.68	1							
5. Mother's perception: Older child's math ability	3.32	0.74	74	21	22.1	.48	-.21	.20	-.05	1						
6. Father's perception: Older child's math ability	3.23	0.80	72	23	24.2	.54	-.02	.31	.06	.42	1					
7. Mother's perception: Older child's German ability	3.06	0.74	74	21	22.1	-.01	.37	.22	.16	.43	.00	1				
8. Father's perception: Older child's German ability	3.03	0.73	72	23	24.2	.01	.23	.18	.20	.01	.37	.35	1			
9. Mother's perception: Younger child's math ability	3.32	0.80	73	22	23.2	.09	-.06	.66	.19	.50	.33	.42	.02	1		
10. Father's perception: Younger child's math ability	3.22	0.74	72	23	24.2	.18	-.02	.69	.37	.23	.49	.16	.16	.63	1	
11. Mother's perception: Younger child's German ability	3.04	0.68	71	24	25.3	-.17	.06	.41	.37	.29	-.07	.47	.15	.49	.23	1
12. Father's perception: Younger child's German ability	3.05	0.75	72	23	24.2	.12	.02	.55	.58	.02	.13	.10	.30	.22	.47	.53

Note. M= Mean, SD = standard deviation, N= present numbers, Missing N = missing numbers, Ratio= missing ratio.

Results

Descriptive Statistics and Preliminary Analyses

As a preliminary analysis, we examined correlations among all study variables separately for the mother, father, older child, and younger child (Table 1). For the individual child's own achievements, the correlation between the older child's math and German grades (r = .13) was much lower than that of the younger child's math and German grades (r = .68). The result is in line with previous empirical findings of a less differentiated academic self-concept for younger than older students, indicating developmental differences across the school years (Weidinger et al., 2019). For the siblings' achievements, the highest correlation between siblings' grades across math and German was r = .31, and the lowest correlation was r = .13. For parents' perceptions, the correlations between a mother's perceptions of a child's abilities in math and German were r = .43 and r = .49 for each older and younger child, respectively, and for fathers' perceptions, they were r = .37 and r = .47. For mothers' perceptions, the correlations between the older and younger child's abilities in different domains ranged from r = .29 to r = .50, whereas they ranged from r = .13 to r = .49 for fathers' perceptions.

Table 2

Variance Decomposition of Parents' Perceptions of Children's Academic Abilities

	Parents' perceptions of children's math ability		Parents' perceptions of children's German ability	
Levels of variance	Level-specific variance	Level-specific partition coefficient	Total level variance	Level-specific partition coefficient
Each Child* Each Parent	.32	32%	.27	27%
Children	.21	21%	.33	33%
Parents	.18	18%	.26	26%
Family	.28	28%	.14	14%

Each Parent's Child-Specific Beliefs

For the first research question, we analyzed the variances in parents' perceptions of children's math and German abilities observed at the four levels, consisting of family, parents, each parent's response on each child, and children in the random intercept models.

We found empirical evidence for each parent's perception of each child's academic ability. The results in Table 2 show substantial amounts of explained variance at the level of each parent's responses for the older- and younger children (i.e., 32% for math and 27% for German). The observed variances at the level of each parent's response on each child indicated each mother's and father's differential perceptions of each child's ability in math and German. At the level of children, the results

showed that 21% of the variance could be explained for math and 33% for German. The observed variances indicate mother's and father's general perceptions of each child. At the level of parents, the results showed that substantial amounts of variance could be explained (18% for math and 26% for German). The observed variances indicated mother's and father's general perceptions of their two children. At the family level, substantial amounts of explained variance (28% for math and 14% for German) were found. The observed variances indicated differences between families and thereby indicated shared parental beliefs about siblings within a family. As predicted, substantial amounts of explained variance in parents' perceptions were found at all levels within the family.

Effects of Siblings' Achievement on Parents' Beliefs Within a Domain

With regard to the second research question, we investigated whether each mother and father used an individual child's own achievement and their sibling's achievement as frames of reference for their parental beliefs. Accordingly, we examined the effect of both older- and younger children's achievement on each mother's and father's perceptions of each older- and younger child's academic ability in the respective domain, separately for math and German. We accounted for individual children's biological sex, children's age, siblings' age difference, and siblings' sex constellation in the analyses.

As predicted, each mother and father used each child's achievement for their beliefs about the child's academic ability in math and German, accounting for individual children's sex, children's age, siblings' age difference, and siblings' sex constellation (see Tables 3 and 4). The association between older and younger children's math achievement and their mother's and father's perceptions of each child's academic ability in the respective domain was positive and significant. For example, a mother's perceptions of her older child's and younger child's abilities significantly predicted each child's math achievement (older child: Math: ß = 0.52, SE = 0.11, $p < .001$, younger child: math: ß = 0.62, SE = 0.09, $p < .001$). Likewise, the association between each sibling's German achievement and a parent's perception of each child's German ability was positive and significant. One exception was that the older child's German achievement did not have an impact on the father's perception of the child's German ability. In line with our expectations, each mother and father generally used each child's own achievements for their perceptions of the child's academic abilities.

In the same regression model, we also found support for the effect of a sibling's achievement on a father's beliefs about the other child's academic ability, but this did not hold for a mother's beliefs (see Tables 3 and 4). Specifically, the association between a younger child's math achievement and a father's perception of the older child's math ability was positive and significant (ß = 0.23, SE = 0.10, $p = .017$). The association between a younger child's German achievement and a father's perception of

the older child's German ability was also positive and significant (ß = 0.26, SE = 0.11, *p* = .016). This indicated that a younger child's math and German achievement positively predicted a father's perception of the first-born child's academic ability in the respective domain above and beyond the child's own achievement. On the contrary, the mother did not use the sibling's achievement as a frame of reference for her beliefs about the other child's academic ability.

Individual children's sex, children's age, siblings' age difference, and siblings' sex constellation were controlled for in all the analyses. For individual children's sex, being male was positively associated with fathers' beliefs about older and younger children's math ability.

Table 3

Social and Sibling Comparison Effects on Each Parent's Perceptions of Each Child's Math Ability

	Mother's perception: older child's math ability			Mother's perception: younger child's math ability			Father's perception: older child's math ability			Father's perception: younger child's math ability		
	β	SE	*p*	β	SE	*p*	β	SE	*p*	β	SE	*p*
Older child's math grade	.52	.11	< .001	-.09	.10	.367	.39	.10	< .001	.05	.11	.619
Younger child's math grade	.17	.10	.097	.62	.09	< .001	.23	.10	.017	.62	.09	< .001
Older child's age	-.03	.18	.890	-.20	.16	.213	.08	.19	.681	.30	.18	.102
Younger child's age	-.03	.17	.858	.14	.15	.360	-.18	.18	.318	-.10	.18	.584
Older child's sex (1 = male)	.34	.19	.077	-.02	.18	.924	.17	.19	.374	-.24	.18	.167
Younger child's sex	.16	.19	.401	.30	.18	.093	.39	.19	.040	.48	.18	.009
Similar-aged sibling (1 = less than 2 years)	-.28	.25	.262	-.30	.23	.185	-.10	.25	.678	.47	.24	.044
Same-sex sibling (1 = same sex)	.17	.20	.395	-.16	.18	.376	-.01	.19	.959	-.15	.19	.433

Note. Sex is coded 1 for male and 0 for female. Similar-aged sibling is coded 1 for less than a 2-year age gap and 0 for others. Same-sex sibling pairs are coded 1 and others are coded.

Table 4

Social and Sibling Comparison Effects on Each Parent's Perceptions of Each Child's German Ability

	Mother's perception: older child's German ability			Mather's perception: younger child's German ability			Father's perception: older child's German ability			Father's perception: younger child's German ability		
	β	SE	*p*	β	SE	*p*	β	SE	*p*	β	SE	p
Older child's German grade	.39	.12	.001	-.10	.12	.394	.14	.12	.251	.01	.11	.896
Younger child's German grade	.19	.10	.064	.38	.11	< .001	.26	.11	.016	.52	.10	< .001
Older child's age	-.08	.19	.678	-.10	.19	.626	.06	.21	.778	.31	.20	.108
Younger child's age	-.05	.18	.781	-.03	.18	.875	-.17	.20	.393	-.16	.19	.405
Older child's sex	-.22	.21	.285	.03	.22	.893	-.52	.22	.016	-.01	.20	.969
Younger child's sex	.01	.20	.970	-.29	.22	.192	.15	.21	.489	-.14	.20	.500
Similar-aged sibling	-.65	.27	.016	-.16	.28	.565	-.56	.28	.048	.29	.26	.270
Same-sex sibling	.33	.20	.095	.09	.21	.663	.20	.21	.327	-.11	.19	.560

Note. Sex was coded 1 for male and 0 for female. Similar-aged sibling was coded 1 for less than a 2-year age gap and 0 for others. Same-sex sibling pairs are coded 1 and others are coded 0.

Table 5

Social, Sibling, and Dimensional Comparison Effects on Each Parent's Perceptions of Each Child's Math and German Abilities

	Mother's perception						Father's perception						Mother's perception						Father's perception					
	Older child's math ability			Younger child's math ability			Older child's math ability			Younger child's math ability			Older child's German ability			Younger child's German ability			Older child's German ability			Younger child's German ability		
	β	SE	*p*	β	SE	p	β	SE	*p*	β	SE	*p*	β	SE	*p*	β	SE	*p*	β	SE	*p*	β	SE	p
Older child's math grade	.63	.11	<.001	-.07	.10	.496	.44	.10	<.001	.01	.10	.911	.01	.12	.914	-.25	.12	.033	.01	.11	.986	-.08	.11	.456
Older child's German grade	-.23	.12	.052	-.12	.10	.196	-.14	.12	.240	.04	.10	.689	.44	.13	.001	-.01	.11	.928	.18	.13	.167	.10	.11	.371
younger child's math grade	.27	.14	.053	.77	.11	<.001	.34	.13	.007	.70	.11	<.001	.20	.15	.165	.31	.14	.025	.23	.14	.104	.44	.13	<.001
Younger child's German grade	-.11	.14	.413	-.23	.11	.037	-.14	.13	.292	-.10	.12	.426	.09	.15	.553	.22	.14	.104	.10	.14	.505	.21	.13	.110
Older child's age	-.14	.18	.453	-.23	.15	.126	.02	.19	.923	.26	.17	.137	-.11	.19	.576	-.20	.18	.278	.05	.21	.824	.24	.19	.198
Younger child's age	.08	.17	.657	.15	.14	.298	-.13	.18	.483	-.07	.17	.695	.01	.18	.954	.12	.17	.469	-.14	.20	.489	-.09	.18	.624
Older child's sex	.16	.20	.437	-.08	.17	.664	.08	.19	.700	-.20	.18	.256	-.16	.21	.441	-.02	.20	.910	-.47	.21	.026	.09	.19	.648
Younger child's sex	.11	.20	.589	.20	.17	.233	.41	.19	.031	.39	.18	.029	.02	.20	.942	-.24	.20	.232	.04	.21	.857	-.30	.19	.117
Similar-aged sibling	-.33	.26	.205	-.29	.22	.189	-.19	.25	.448	.48	.23	.033	-.63	.27	.020	-.19	.26	.470	-.48	.27	.079	.33	.25	.178
Same-sex sibling	.23	.20	.255	-.18	.17	.313	.09	.19	.656	-.19	.18	.295	.43	.21	.047	.04	.21	.856	.20	.21	.328	-.17	.20	.389

Note. Sex is coded 1 for male and 0 for female. Similar-aged sibling is coded 1 for less than a 2-year age gap and 0 for others. Same-sex sibling pairs are coded 1 and others are coded 0.

Dimensional Comparison Effects of Siblings' Achievement on Parents' Beliefs Across Domains

With regard to the third research question about dimensional comparison effects, we added siblings' achievement in nonmatching domains as additional predictors. Specifically, we analyzed the effects of both the older and younger children's achievements on each mother's and father's perception of each child's academic ability in matching as well as in nonmatching domains. For instance, we analyzed whether a child's and their sibling's math and German achievement (i.e., four independent variables) predicted mothers' perceptions of a child's math ability. We controlled for individual children's sex, children's age, siblings' age difference, and siblings' sex constellation in the analyses.

When siblings' math achievement was added as an additional predictor of parents' beliefs about children's German ability, most of the associations between each child's German achievement and each parent's beliefs about the child's German ability became nonsignificant (for details, see Table 5). Whereas when siblings' German achievement was added as an additional predictor, most of the associations between each child's math achievement and each parent's beliefs about the child's math ability remained significant.

The association between the younger child's math achievement and the father's perception of the older child's math ability also remained positive and significant. For individual children's sex, being male remained positively associated with a father's beliefs about the younger child's math ability.

Regarding individual children's own achievements in different domains, we found support for dimensional comparison effects on parents' beliefs about a younger child's academic ability. In line with general findings on dimensional comparison effects (Möller et al., 2020), the association between a younger child's German achievement and the mother's perception of the child's math ability was negative and significant (ß = -0.23, SE = 0.11, p = .037). This means that when the younger child got good grades in German, mothers tended to have lower beliefs about the child's math ability. Interestingly, the association between a younger child's math achievement and both parents' perceptions of the child's German ability was positive and significant (mother: ß = 0.31, SE = 0.14, p = .025, father: ß = 0.44, SE = 0.13, p < .001). This means that when the younger child got good grades in math, mothers and fathers tended to have higher perceptions of the child's German ability. Except for these three regression paths, we did not find dimensional comparison effects of an individual child's own achievement on parents' perceptions of the child's ability in nonmatching domains.

Regarding siblings' achievement across domains, we found support for dimensional comparison effects of siblings' achievement in a domain on a mother's beliefs about the younger

child's academic ability in the other domain (Table 5). Specifically, the association between the older child's math achievement and the mother's perceptions of the younger child's German ability was negative and significant (ß = -0.25, SE = 0.12, p = .033), in line with the general findings of negative dimensional comparison effects on competence beliefs (Möller et al., 2020). This finding indicated that mothers used a sibling's achievements for their perceptions of the other child's ability across domains. We did not find such an effect in the other regressions.

Discussion

On the basis of expectancy-value theory, we found empirical evidence of parents' child-specific beliefs about academic ability. Following prior studies, we further employed the I/E model to investigate whether each parent constructed their child-specific academic ability beliefs on the basis of social and dimensional comparison processes. Yet, we extended prior findings by focusing on comparison processes that occur within a family. Specifically, we tested social and dimensional comparison effects of siblings' achievements on parents' beliefs about each child's academic ability in math and German. Our findings showed tentative evidence that parents use each child's own achievement and their sibling's achievement as frames of reference for their beliefs about each child's academic ability within and across domains. Yet, a lack of a clean pattern in the results along with data from only a small number of 95 families in our analyses calls for a cautious interpretation of our results. Nevertheless, many of our results generally support the joint effect of individual children's own achievement and their siblings' achievement on parents' child-specific ability beliefs in line with what has been hypothesized in expectancy-value theory's model of family influences.

The largest amount of variance (i.e., 29.5%) was explained for each parent's beliefs about each child's ability in math and German. In addition, both parents' beliefs about each child's math and German ability also differed between siblings, which explained approximately 27% of the variance in parents' beliefs. This means that mothers' and fathers' beliefs about their children's abilities were more often different for different siblings rather than general beliefs that they applied across siblings. This finding shed lights on each parent's child-specific ability beliefs in line with expectancy-value theory's model of family influences (Eccles, 2007). Concerning the idea that parents' beliefs have an impact on parenting practices and behavior as well as children's educational development (Eccles, 2007; Eccles, Arberton, et al., 1993; Gladstone et al., 2018; Miller, 1988), parents' differential beliefs about siblings' academic abilities may contribute to differences in siblings' educational development.

In addition, the empirical evidence that each parent has child-specific beliefs has important implications for research. Most prior studies have looked at one child and one parent to represent general parental beliefs or have used aggregated data to represent the mother's and father's average view on their children's academic abilities (Dai, 2002; Van Zanden et al., 2017; Wolff et al., 2020).

Given that parents' beliefs largely differed between siblings, running the analyses with each parent's child-specific beliefs is crucial to produce comparable results across studies. Additional consideration should be given to a parent's gender for investigating parents' beliefs as our study showed differences between mothers' and fathers' beliefs about each child's academic abilities. Perhaps prior studies' inconsistent results on effects of social and dimensional comparisons on parents' beliefs about children's abilities might be related to the different specifications of parents' beliefs used in individual studies.

Both mothers and fathers used each child's own achievement as a frame of reference for their beliefs about the child's academic abilities. The higher a child's achievement in a certain academic domain, the higher the parents' beliefs were about the child's academic ability in that domain. This highlights that mothers and fathers adapt their beliefs to individual children's own achievement. Generally, parents' beliefs are viewed as predictors of parents' behavior and children's educational outcomes (Eccles, 2007; Eccles, Arberton, et al., 1993; Gladstone et al., 2018; Miller, 1988), yet our findings highlighted the opposite effect of children's achievement on their parents' perceptions of the child's academic capacity. In other word, each child's own academic achievement contributed to their parents' perceptions of the child's academic ability, which, in turn, could further diversify parents' beliefs about siblings as shown in previous studies (Briley et al., 2014).

Fathers tended to use a sibling's achievement as an additional frame of reference for their beliefs about the other child's academic ability, independent of the child's own achievement. Interestingly, a younger child's higher achievement had a positive impact on the father's perception of the older child's academic ability in the respective domain, controlling for the sibling's gender, the sibling's age, siblings' age difference, and siblings' gender constellation. Especially, a younger child's math achievement had a robust effect on the father's apperception of the older child's math ability even when including the children's German achievement as an additional covariate. In a study of a large sample of siblings, academic ability and achievement were higher for the first-born child than a later born children (e.g., Conley et al., 2007). In this regard, a younger child's achievement could have gained more attention from fathers regarding their generally lower academic achievements than the older ones. Nevertheless, the positive effect of a younger child's achievement on a father's beliefs about the older child's academic abilities indicates that fathers tend to perceive siblings as being associated rather than as being comparison targets as shown in the strong positive correlations between fathers' beliefs about an older and younger child's abilities, especially in the math domain (r = .47).

On the other hand, dimensional comparison effects tended to be more pronounced for mothers' beliefs about each child's academic abilities than fathers'. Mothers considered not only each

child's achievement but also their sibling's achievement for their perceptions of the child's academic ability in the contrasting domain. Specifically, when the younger child got good grades in German, mothers tended to have lower beliefs about the child's math ability, similar to a previous finding of negative dimensional comparison effects on parents' beliefs (Wolff et al., 2020). However, considering that mother's beliefs about the second child's math and German achievement were strongly correlated (r = .49), the current finding of the negative dimensional effect on mothers' beliefs should be interpreted with caution. In addition, when an older child got good math grades, mothers tended to have lower perceptions about the younger child's German ability. This indicates a cross-sibling influence on mothers' beliefs across different academic domains. Given that we did not find such effects on fathers' beliefs, it could be speculated that mothers are more likely to dimensionally compare children's achievement in one domain with their achievement in the other domain. However, as we found only very limited and inconsistent dimensional comparison effects only on mothers' beliefs, our finding is more comparable to previous studies that did not find dimensional comparison effects on parents' beliefs about children's academic abilities (Dai, 2002; Van Zanden et al., 2017).

Interestingly, we found evidence of a positive effect of dimensional comparisons on mother's and father's beliefs about their younger child's academic ability. When the younger child got good grades in math, mothers and fathers tended to have higher perceptions of the child's German ability as well. This might indicate that parents tend to have more general perceptions of a younger child's achievements in diverse academic domains. Given that the correlation between math and German achievement was much higher in younger children (r = .68) than in older children (r = .13), mothers and fathers correspondingly tended to have less differentiated beliefs about their younger child's achievements across domains (mother's belief: r = .49, father's belief: r = .47) than about their older child's achievements (mother's belief: r = .43, father's belief: r = .37). Nevertheless, the younger child's German achievement did not serve as a frame of reference for parents' beliefs about the same child's math ability. It seems that mothers and fathers pay more attention to the younger child's math achievement than the younger child's German achievement.

The different patterns of social and dimensional processes between mothers and fathers might have contributed to differences in parents' beliefs about each child's ability and in both siblings' academic abilities as shown in the substantial variance in parents' beliefs observed at the levels of children and the level of each parent on each child. Siblings' achievement had more influence on fathers' beliefs, whereas the effects of dimensional comparisons of children's achievements across different academic domains tended to be more pronounced for mothers' beliefs. In addition, for the younger child's sex, being male had a consistent effect on a father's beliefs about the younger child's and the older child's math abilities. Our finding corresponds to prior empirical findings that parents'

gender (Eccles et al., 1990; Gladstone et al., 2018; McGillicuddy-DeLisi, 1982) and a child's and their sibling's characteristics—consisting of gender (Dai, 2002; Eccles et al., 1990; Quadlin, 2019), birth order (Cicirelli, 1978; Lindert, 1977), and age (Whiteman et al., 2003)—jointly differentiate parents' perceptions about each sibling's academic ability during parent-child interactions as hypothesized in the model of family influences (Eccles, 2007).

Overall, our findings showed how each parent's beliefs vary on multiple levels of social systems within a family and revealed several interesting patterns of effects of social and dimensional comparisons on parents' beliefs about each child's academic ability. The results are comparable to previous findings on parents' beliefs based on the I/E model (Dai, 2002; Van Zanden et al., 2017; Wolff et al., 2020) yet further extend the focus on parents' beliefs about siblings within the family. Although we did not find a consistent and clean pattern of comparison processes of siblings' achievements within and across domains for parents' beliefs, our findings consistently highlight that each parent's child-specific ability beliefs are related to the distinctive comparison processes involved in the construction of parents' beliefs about each sibling. Accordingly, our findings may contribute to evidence for the joint influence of children's, siblings', and parents' characteristics on each parent's child-specific ability beliefs as hypothesized in expectancy-value theory's model of family influences. We urge researchers to be careful about how they specify parents' beliefs to produce comparable results across the studies.

However, readers should interpret our results with great caution as we had data from only a limited number of 95 families for our analyses. Despite this methodological limitation, the present study implies that the focus should be shifted to diverse influences, which jointly shape parents' child-specific ability beliefs within the family. Thus, future studies should be conducted to replicate the results with larger samples to provide more reliable and valid findings to verify the complex mechanisms involved in each parent's child-specific ability beliefs.

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4. Study 2: Why Do Siblings Differ in Their Learning Motivation and Perceptions of Parental Support? Reciprocal Relationships Between Parental Support and Each Sibling's Learning Motivation

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Abstract

This study examined whether reciprocal relationships between four dimensions of parental support (i.e., parents' expectations, parents' emotional support, parents' learning encouragement, and parental control) and students' learning motivation differed between siblings. We analyzed TwinLife Data from 2,083 school-aged Monozygotic (MZ) and Dizygotic (DZ) twins who were surveyed at age 11 and age 13. Reciprocal relationships between parents' child-specific learning encouragement and each child's learning motivation were observed only in DZ twins, and the relationships differed between siblings: A DZ twin who perceived higher parental learning encouragement than their co-twin at age 11 had higher learning motivation at age 13, and the twin who had higher learning motivation than their co-twin at age 11 had higher perceptions of parental learning encouragement at age 13. Such reciprocal relationships were not observed for other dimensions of parental support and not for MZ twins. When children's personality, sex, and school grades were added as covariates, the significant reciprocal relationships found in within-twin-pair regressions for DZ twins remained robust. MZ and DZ twins differed significantly in the effects of individual children's learning motivation at age 11 on their perceptions of parental learning encouragement at age 13, indicating an effect of sibling resemblance on whether parents' support for the siblings was similar or different.

Why Do Siblings Differ in Their Learning Motivation and Perceptions of Parental Support? Reciprocal Relationships Between Parental Support and Each Sibling's Learning Motivation

Parents have a major impact on educational achievement (Castro et al., 2015) and its major drivers, such as learning motivation (Eccles, 2007). As the family is the child's primary social group and provides guidance throughout children's school careers, parental encouragement and support offer a foundation for children's perceptions of their own intellectual abilities and the extent to which they value learning and education (Eccles et al., 2006; Parsons et al., 1982). Parental influences are multifaceted and multidimensional (Bempechat & Shernoff, 2012), and multiple dimensions of parental influences have been studied for their effects on motivation. In particular, children's perceptions of parental support, warmth, and control have been found to affect children's learning motivation (Dinkelmann & Buff, 2016).

Researchers have traditionally investigated one child per family when studying the impact of parental support on children's motivation (Briley et al., 2014; Plomin & Daniels, 2011; Tucker-Drob & Harden, 2012). In doing so, most studies have considered differences across families (e.g., Plomin & Daniels, 2011). Yet, parenting is—at least to some degree—differently and subjectively experienced within sibling pairs (Asbury et al., 2003; Daniels & Plomin, 1985; Plomin & Daniels, 2011; Turkheimer & Waldron, 2000), which warrants a look at differential associations between parental support and children's motivation within the same family. Specifically, children in the same family may perceive parental support differently, and thereby, the effect of perceived parental support on learning motivation may differ across siblings (Briley et al., 2014). According to expectancy-value theory's model of family influences (Eccles, 2007), it can be assumed that parents' child-specific perceptions, an individual child's characteristics (e.g., sex, achievement, and personality), and siblings' characteristics will result in differences in effects of parents' support on siblings' educational development.

Using a longitudinal sample of 2,082 preadolescent twins (age 11 at the first measurement occasion), we investigated the reciprocal relationships between child-specific perceptions of parental support (parents' expectations, emotional support, learning encouragement, and control)[1] and a child's individual learning motivation. In a first step, we studied whether the reciprocal relationships differed between twins within and across families. Twin data are particularly well-suited for investigating the differential effects of parental support while holding specific sibling characteristics (e.g., age and sex) constant. In order to test whether the reciprocal relationships could be explained by children's characteristics, we controlled for each individual child's characteristics (sex, school grades, conscientiousness, openness, and neuroticism) and the socioeconomic status (SES) of the family in the

[1] Emotional support is one of the four specific dimensions of parental support. We will always refer to it as emotional support. Otherwise, when we refer to support, we mean the overarching more general construct.

next step. We also tested which characteristics of each individual child or which characteristics that were shared between siblings influenced the associations. Finally, we tested whether the association between children's perceived parental support and children's learning motivation differed between MZ and DZ twins to investigate whether sibling resemblance affected the reciprocal exchange of influence between parents and siblings.

Effects of Parents' Practices on Children's Learning Motivation

Many theoretical frameworks of achievement motivation, such as expectancy-value theory (Eccles, 2007; Muenks et al., 2018) and self-determination theory (Grolnick et al., 1991; Ryan & Deci, 2000), emphasize the important role that parents play in children's motivation. Children's interactions with their parents constitute an important context for the development of children's achievement motivation across different ages (Pomerantz et al., 2012; Pomerantz & Moorman, 2010). Accordingly, empirical studies have reported effects of parental practices and support on children's educational motivation, such as authentic interest and enjoyment in learning and deep problem solving, ideal engagement in learning and achievement in school, and competence beliefs (Eccles, 2007; Pomerantz et al., 2007).

Multiple dimensions of parental support have been studied for their effects on motivation, revealing substantial differences across different dimensions (Barger et al., 2019). The current paper focuses on four dimensions of parental support (parents' expectations of children's school performance, parents' emotional support, parents' learning encouragement, and parental control) that we will introduce next, along with prior empirical evidence on how they are associated with students' motivational development. It is important to note that—in addition to differentiating across dimensions—studies have also used a variety of instruments and items to tap parental support and involvement, which adds a certain degree of incoherence across the results and interpretations of the results of various studies (Fan et al., 2012; Gonzalez-DeHass et al., 2005).

Parents' expectations generally refer to parents' aspirations and expectations for their children to perform well in the educational setting (Fan & Chen, 2001). They are often measured by children's reports, with items such as parents' aspirations for their children's academic success (Fan & Chen, 2001), for their children to obtain higher degrees (Rimkute et al., 2012), and for their children to perform well in school (Bowen et al., 2012). Measures of parents' expectations are frequently used in studies that are based on expectancy-value theory's model of family influences (Eccles, 2007). On the one hand, the results from empirical studies have shown that the diverse constructs of parents' aspirations for their children's success in school are positively related to students' motivation in school (Fan et al., 2012) and students' educational expectations (Rimkute et al., 2012). However, in contrast

to the reported positive effects of parents' expectations on children's educational motivation constructs, a few other empirical studies have indicated that parents' expectations may also be related to children's stress from academic expectations (Ma et al., 2018; Tan & Yates, 2011). Based on the self-discrepancy model (Higgins, 1989), it was argued that parents' expectations may cause discrepancies between students' perceptions of parents' expectations and students' performance (Wang & Heppner, 2002). In addition, when students cannot meet their parents' high expectations, parents may respond critically to their children's failures (Ma et al., 2018), which may further lead to children's performance-avoidance goal orientation (Madjar et al., 2015). Taken together, high parental expectations can have both favorable and unfavorable consequences in terms of the development of students' educational motivation. Related to this, a review of the dimensions of parents' expectations found that the facets of parents' expectations that are based on a general agreement about the value of a good education between children and their parents tended to have a positive effect, but other types of expectations that push parents' standards on their children may have a negative effect on students' educational outcomes (Jeynes, 2011).

Parents' emotional support refers to parents' emotional responsivity to children's psychological needs to relate to and feel close to their parents in their educational development (Connell & Wellborn, 1991; López Turley et al., 2010; Paulson, 1994), and it is often used in studies that are based on self-determination theory (Ryan & Deci, 2000; Ryan & Powelson, 1991) and attachment theory (Pomerantz et al., 2012). There are multiple dimensions of parents' emotional support involving both relationship quality and practices. It is often measured by children's reports of parents' communication with their children about interests in and out of school (Paulson, 1994), the extent to which parents help children with their homework, how much parents discuss children's progress in school with them (Peng & Wright, 1994), parents' relationships with their children, and children's sense of obligation to their parents (Pomerantz et al., 2012). Empirical studies have shown that a close relationship between children and their parents is positively related to students' motivational orientation and learning outcomes (Furrer & Skinner, 2003; Paulson, 1994; Peng & Wright, 1994; Pomerantz et al., 2012; Pomerantz, Wang, et al., 2005; Ryan & Powelson, 1991; Wang & Eccles, 2012). Despite the association between the parent-child relationship and children's academic motivation, it alone might not be sufficient for enhancing children's achievement motivation (Pomerantz et al., 2012).

The third dimension we focused on in the present study may best be called parents' learning encouragement. It consists of items that refer to parents' encouragement of their children's effort and endeavors to learn in an academic setting (Boonk et al., 2018; Khan & Siraj, 2012), exemplified as parental support for autonomous learning (Martinez-pons, 1996) and parents' explanations of the importance of engaging in learning-related behavior (Joussemet et al., 2008). This dimension includes

elements of what has been called *parental support for autonomous learning*. More generally, the dimension includes elements of parents' behaviors that are believed to be effective for children's intrinsic learning motivation in self-determination theory (Grolnick et al., 1991; Ryan & Deci, 2000). In fact, there is empirical evidence that parents' learning encouragement has a positive effect on children's self-regulated learning motivation constructs (Joussemet et al., 2008; Martinez-pons, 1996) and academic achievement (Boonk et al., 2018; Khan & Siraj, 2012).

Finally, parental control is defined as intrusive parental pressure to control children's autonomy, thoughts, feelings, and behavior in the learning context through commands, punishment, or coercive interactions (Barber, 1996; Baumrind, 1971; Grolnick & Pomerantz, 2009; Nelson & Crick, 2002). However, multiple forms of parental control have been measured in empirical studies, thus yielding inconsistent findings. On the one hand, similar to parental structure, the facets of parental control (e.g., supervision, discipline, and behavioral control) are likely to provide guidance for children, which is important for children to develop competence (Grolnick & Pomerantz, 2009). On the other hand, parental control, consisting of items that measure coercive parental behaviors (e.g., parental pressure, intrusiveness, an assault on children's individuality, and punishment) have been found to have a negative effect on children's psychological development and self-regulated learning motivation (Grolnick & Pomerantz, 2009; Grolnick & Ryan, 1989).

Investigating the different dimensions of parental support described above is important because differences in parenting behaviors have been shown to be associated with differential changes in student motivation in longitudinal studies. For instance, perceived parental control had a positive longitudinal impact on extrinsic motivation (Bronstein et al., 2005) but not on intrinsic motivation (Grolnick, 2003), whereas parental encouragement of children's engagement in the learning process had a positive longitudinal impact on intrinsic academic motivation in math and science (Gottfried et al., 1994; Gottfried et al., 2009).

Reciprocal Effects Between Children's Perceptions of Their Parents' Support and Children's Learning Motivation

Most prior studies that have centered on how parents influence their children's educational outcomes have focused primarily on what parents do for their children (for reviews and a meta-analysis, see Boonk et al., 2018; Jeynes, 2007; Taylor et al., 2004). Despite the impact parents can have on their children's achievement motivation and actual achievements (Grolnick et al., 1997), less is known about how children's motivation reciprocally affects parents' behavior and support. Although children's educational motivation is generally believed to be affected by parents, the reciprocal influences between children's motivation and the surrounding environment have also been established (Bell,

1968). This means that the direction of influence is not only from parents to children but also from children to parents and is thus bidirectional (Kuczynski & Parkin, 2007; Sameroff, 2009). Importantly, the assumed bidirectional influence between parents and children suggests that children's motivation and achievement should be viewed not only as outcomes but also as predictors of the parental support that they receive (Bell, 1968).

A few empirical studies have shown reciprocal effects between children's achievement and motivation and the diverse facets of parental support (Briley et al., 2014; Dumont et al., 2014). For instance, reciprocal relationships were reported for different dimensions of parental support and students' academic functioning (Dumont et al., 2014). Specifically, higher parental control resulted in lower academic functioning for students from Grade 5 to Grade 7, whereas students' lower academic functioning was related to higher parental control across the 2 school years (Dumont et al., 2014). Similarly, higher parental responsiveness and structure in Grade 5 was associated with students' higher academic functioning in Grade 7, whereas students' higher academic functioning in Grade 5 resulted in higher parental responsiveness and structure in Grade 7 (Dumont et al., 2014). Similar findings on reciprocal relationships between parents' expectations and children's motivational constructs have been reported by a number of additional empirical studies (e.g., Lugo-Gil & Tamis-LeMonda, 2008; Tucker-Drob & Harden, 2012; Zhang et al., 2011). The rationale behind the reciprocal effect is that children's learning motivation influences whether parents decide to provide and how they provide an optimal level of scaffolding in their interactions with their child in the learning situation (Mata et al., 2018).

The significant reciprocal associations between a child's academic functioning and parents' expectations and involvement found in prior studies (Briley et al., 2014; Dumont et al., 2014) have several important implications. Given that children's academic functioning and parents' expectations and involvement mutually reinforce each other, children's motivation should be viewed not only as an educational outcome but also as an important antecedent of the parental support that they receive. In such a transactional exchange of influence with parents, children are not just passive recipients of their parents' influence but are rather active socializers with their parents such that they co-create the learning environment in the home. Accordingly, children's endeavors to communicate their high motivation is emphasized for receiving higher parental expectations and support. Based on prior findings on transactional influences between children and parents (Dumont et al., 2014; e.g., Lugo-Gil & Tamis-LeMonda, 2008; Tucker-Drob & Harden, 2012; Zhang et al., 2011), it is reasonable to look further at how children's learning motivation and the diverse dimensions of their parents' support (e.g., parents' emotional support, parents' learning encouragement, and parental control) reciprocally affect one another.

Within-Family Differences in Motivational Dynamics

Given that prior studies have reported reciprocal associations between parental support and children's motivation (e.g., Lugo-Gil & Tamis-LeMonda, 2008; Tucker-Drob & Harden, 2012; Zhang et al., 2011), one may further ask how these reciprocal associations play out in the larger family context with more than one child. In the ongoing bidirectional socialization process between parents and children, characteristics of children and the social context moderate parents' ability to help children meet their psychological needs for intrinsic, autonomous learning motivation (Pomerantz, Grolnick, et al., 2005). Accordingly, the bidirectional effects of the child and the environment are assumed to create an individual child-specific context across time, which further affects the development of the child (Sameroff, 2009). Based on this viewpoint, the transactional influence between each child and parent is assumed to differentiate parental support between siblings because siblings differ from each other in their characteristics, and parents adapt their behavior according to each sibling's individual characteristics. In other words, the reciprocal association between an individual child's achievement motivation and parental support should differ between siblings.

The hypothesis of differences between siblings in their reciprocal relationships with their parents has been empirically supported. Briley et al. (2014) reported finding transactional associations between a parent's educational expectations and a child's achievement and learning approach in within-twin-pair associations beginning in kindergarten and ending in fifth grade (Briley et al., 2014). The significant reciprocal association with parents' expectations found in within-twin-pair regressions indicates that the reciprocal association between parents' expectations and a child's academic adjustment differed between siblings. More specifically, this means that a child who perceived higher parental expectations than their sibling had higher motivation and achievement 6 years later, and a child who had higher achievement or higher learning motivation than their siblings tended to perceive higher parental expectations after 6 years, controlling for prior academic adjustment and their previous perceptions of parental expectations, respectively. This finding highlights that differences in siblings' motivation and achievement reciprocally affected their perceptions of parents' expectations throughout the school years. Given that parents' child-specific beliefs are assumed to affect parents' behaviors (Eccles, 2007; Wigfield et al., 2015), one may further ask if differences between siblings in their motivation or achievement also reciprocally differentiate diverse dimensions of parents' support for each sibling.

Yet, it is not only differences between siblings in motivation and achievement but in their other characteristics as well that are assumed to have an influence on the bidirectional socialization between a parent and each child in a family. Eccles and colleagues (Eccles, Arberton, et al., 1993) proposed a model of parental influences on children's motivation and achievement, which explains the dynamics

of academic socialization within the family. The model (Eccles, Arberton, et al., 1993) proposes that individual children's and siblings' characteristics, such as sex, past performance, aptitudes, temperament, attitudes, and birth order should affect parents' child-specific beliefs and behavior, which in turn should influence individual children's educational outcomes. The theoretical viewpoint implies that children in the same family will experience their parents in different ways either because each individual child's characteristics of sex, age, personality, and achievements and their siblings' characteristics will determine the parental support that they receive (Eccles, 2007) or because they will perceive their parents' support differently (Dinkelmann & Buff, 2016; Grolnick et al., 1997). Either way, the characteristics of each individual child may determine the reciprocal exchange of influence between each parent and each sibling as assumed from the viewpoint of the transactional model (Bell, 1968; Kuczynski & Parkin, 2007; Pomerantz, Grolnick, et al., 2005; Sameroff, 2009) and the model of parental influences from the expectancy-value theory framework (Eccles, Arberton, et al., 1993).

Empirical studies have correspondingly presented evidence of substantial effects of individual children's characteristics (e.g., sex, personality, and birth order) on parents' beliefs and behaviors as well as their motivation. Such prior studies have found that parents' beliefs and behaviors have significant relationships with children's biological sex (Kidwell, 1981; Šimunović & Babarović, 2020), birth order (Hotz & Pantano, 2015; Musun-Miller, 1993; Someya et al., 2000), and children's personality traits, such as extraversion, agreeableness, and conscientiousness (Tamm et al., 2021; Vigouroux & Scola, 2018; Werneck et al., 2014). Relatedly, these previous empirical studies have reported that educational motivation constructs are associated with a child's biological sex (Gonida et al., 2007; Rimkute et al., 2012; Schoon & Polek, 2011), personality traits of openness, conscientiousness, and neuroticism (Caprara et al., 2011; Komarraju & Karau, 2005; Komarraju et al., 2009; Sorić et al., 2017), school grades in math and German (Wigfield & Karpathian, 1991), and SES (Gonida et al., 2007). These findings show how important it is to consider individual children's characteristics, such as sex, birth order, prior achievements, and personality traits, when investigating reciprocal associations between parental support and siblings' learning motivation.

Sibling Resemblance as a Moderator of Academic Socialization Within the Family

Assuming that the characteristics of individual children may determine the reciprocal exchange of influence between parents and each sibling (Bell, 1968; Eccles, Arberton, et al., 1993; Kuczynski & Parkin, 2007; Pomerantz, Grolnick, et al., 2005; Sameroff, 2009), it is crucial to consider the case of siblings who are very similar in their characteristics. From a social comparison theory perspective (Festinger, 1954), parents' perceptions of sibling similarity affect the extent to which parents associate a child with their siblings and how similarly or differently parents treat the siblings. Given that mothers substantially noticed siblings' differences (Schachter et al., 1978), it is reasonable to assume that

similarities or differences between siblings might be related to the extent to which parents treat them similarly or differently.

The hypothesis that parents' beliefs and support are likely to differ by sibling resemblance was empirically supported by studies comparing monozygotic (MZ) and dizygotic (DZ) twins. MZ and DZ twins differ in the average percentages of genes they share with co-twins (Plomin & Daniels, 2011). Whereas MZ twins have matched genes, DZ twins share approximately 50% of their genes, similar to nontwin siblings. Thereby, MZ and DZ twins' characteristics reflect different degrees of similarity between siblings (Plomin & Daniels, 2011). Accordingly, studies have reported that parents tend to perceive MZ twins as more similar than DZ twins and nontwin siblings (Reiss, 2003). MZ twins have been found to be more likely to receive similar treatment from their parents than DZ twins (Lytton, 1977; Morris-Yates et al., 1990; Rowe, 1981). In addition, parents were perceived to treat MZ twins more similarly than DZ twins even when they were mistaken about the twin's zygosity (e.g., actual MZ twins were believed to be DZ twins by parents and vice versa; Lytton, 1977). Another study also reported that parents' knowledge of zygosity did not affect the way the parents treated the children (Cohen et al., 1977). Such studies have consistently highlighted that parents react to perceived similarity within MZ twin pairs more than they do to DZ twins (Furman & Lanthier, 2002). Taken together, sibling resemblance should have an impact on the extent to which parents associate a child with their sibling (Reiss, 2003) and how parents change their actions to accommodate a child's individuality and needs. This hypothesis is also consistent with the hypothesized importance of interpersonal similarity in how people compare themselves with one another according to social comparison theory (Festinger, 1954). Thus, it is reasonable to assume that sibling resemblance will also have an impact on whether academic socialization with parents differs across siblings or not.

The Present Study

The current paper extends prior longitudinal research on parents' effects on children's learning motivation (e.g., Bowen et al., 2012; Pan & Gauvain, 2012; Pinquart, 2016) by considering effects of children's motivation on parents' behavior. Notably, we took a closer look at whether the transactional effect between children's perceptions of parental support and children's learning motivation differs within twin pairs or between twins (i.e., across families,). Accordingly, we conducted all the analyses separately for MZ and DZ twins. As a next step, we aimed to determine whether the reciprocal associations between children's perceptions of parental support and children's learning motivation in within-twin-pair regressions and between-twin-pair regressions remained robust while controlling for an individual child's and their sibling's characteristics. Finally, we compared very similar twin pairs (MZ) with less similar twin pairs (DZ) to investigate whether the reciprocal associations found in within-twin-pair regressions and between-twin-pair regressions differed by the similarity of the siblings.

To this end, we used a large, representative sample of MZ and DZ twins in Germany from the TwinLife longitudinal study (Diewald, 2021; Hahn et al., 2016). Specifically, we used first-wave and second-wave data collected from school-aged twins in a cohort: twins who were 11 years old in the first wave and 13 years old in the second wave. Notably, only same-sex DZ twins were sampled in this study so that all twin pairs had the same sex. By using the TwinLife data (Diewald et al., 2020) of MZ and DZ twins, we were able to investigate siblings' shared perceptions of each parent as well as each individual child's differential perception of each parent, holding constant the children's age, sex, birth order, and genetic difference (in MZ twins). We focused on the set of constructs described above, including parents' expectations (Bowen et al., 2008; Fan & Chen, 2001; Rimkute et al., 2012), parents' emotional support (Connell & Wellborn, 1991; López Turley et al., 2010; Paulson, 1994; Peng & Wright, 1994), parents' learning encouragement (Boonk et al., 2018; Khan & Siraj, 2012; Martinez-pons, 1996), and parental control (Baumrind, 1971; Grolnick, 2003; Grolnick & Pomerantz, 2009; Joussemet et al., 2008; Nelson & Crick, 2002; Su et al., 2015).

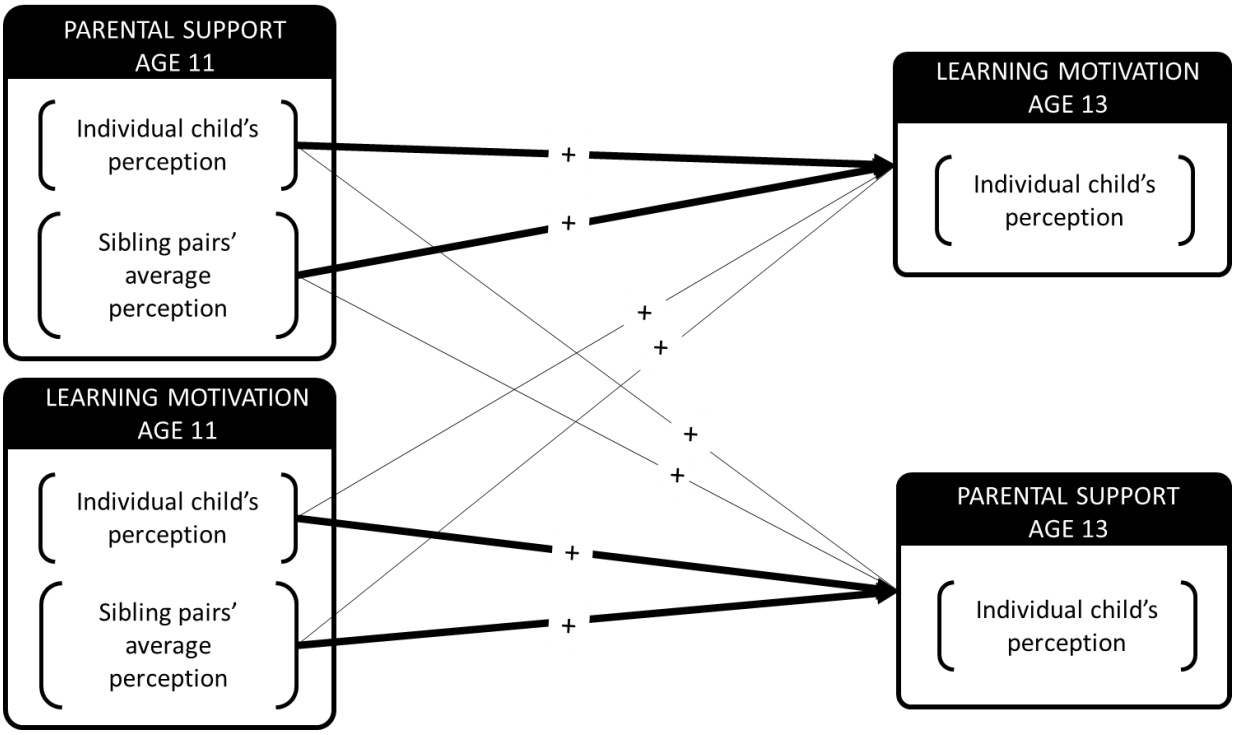
First, we investigated whether these associations between the four dimensions of parental support and children's learning motivation still held when analyzed for cross-lagged effects and in longitudinal analyses. That is, we examined whether they were consistent when the variables were measured at different times in the children's lives. Specifically, we investigated the cross-lagged effects of children's perceptions of parental support and children's learning motivation from age 11 to age 13, controlling for the respective measure of support at age 11 (Figure 1). With this investigation, we aimed to find generalizable evidence for reciprocal effects between children's perceptions of parental support and children's learning achievement across the timepoints. Furthermore, we aimed to gain an integrative understanding of reciprocal effects at both the within- and between-family levels of analyses. Thus, we investigated cross-lagged effects within sibling pairs and across families. Accordingly, we conducted all the analyses separately for MZ and DZ twins.

Second, we were interested in whether the reciprocal relationships between children's perceptions of parental support and children's learning motivation were affected by the child's and their sibling's characteristics. Relatedly, previous empirical studies have reported that the associations between parental support and children's educational motivation constructs are related with children's biological sex (Gonida et al., 2007; Rimkute et al., 2012; Schoon & Polek, 2011), the personality traits of openness, conscientiousness, and neuroticism (Caprara et al., 2011; Komarraju & Karau, 2005; Komarraju et al., 2009; Sorić et al., 2017), school grades in math and German (Wigfield & Karpathian, 1991), and SES (Gonida et al., 2007). Accordingly, for all the analyses, we added these variables as covariates. In so doing, we aimed to see if the reciprocal effects found for each child in a sibling pair would be generalizable and robust despite the addition of the covariates.

Third, similarities or differences between siblings might be related to the extent to which parents treat them similarly or differently (Festinger, 1954). Thus, we expected that MZ and DZ twins might differ in the transactional association between parental support and an individual child's learning motivation regarding the sibling pairs' different levels of similarity. We hypothesized that children might perceive greater differences in their parents' support of each sibling when the siblings differed more from one another. As we computed all the analyses separately for MZ and DZ twins, we compared whether the effects differed between DZ and MZ twin pairs for each regression path in the cross-lagged models as well as in the models with the additional covariates.

Figure 1

Hypothesized Cross-Lagged Model.



Method

Data

We reanalyzed longitudinal data from the TwinLife study that included representative samples of MZ and DZ twins and their families in Germany (Diewald et al., 2020) made available by the Leibniz-Institute for the Social Sciences (GESIS). The ethics commission of the German Psychological Association (protocol numbers: RR 11.2009 and RR 09.2013) confirmed that the TwinLife study was

conducted in line with the ethical standards for research with human participants (Mönkediek et al., 2019, p. 546). During the field phase, active consent was obtained from all participants (Hahn et al., 2016).

For longitudinal analyses, we used the TwinLife data collected in the first wave in the years 2014 -2015 as well as the data collected in the second wave in the years 2016-2018. To validate the representativeness of the sampling strategy, Twinlife compared the sample with a nationally representative sample from the German household survey (i.e., the 2013 Microcensus) with regard to the twins' region of residence (i.e., East and West Germany), community size, German citizenship status, the highest educational and occupational status of the twins' parents, and the parents' monthly income. The distributions of the variables in the TwinLife sample were roughly comparable to the corresponding population values (Lang & Kottwitz, 2020). A population-based sample of 4,907 twin families with 11,405 individual MZ and DZ twins, the twins' siblings and partners for adult twins, their biological or adoptive parents, and step-parents (if applicable) were administered the survey when the first round of data collection began in 2014. Among them, 3,900 families with 7,742 twins were administered the survey again in the second round of data collection, excluding those who did not respond due to a change of address or withdrawn consent. Every other year, interviewers administered the survey by conducting face-to-face interviews (i.e., computer-assisted personal interviews), computer-assisted self-interviews, or paper-and-pencil interviews or by administering online questionnaires. In the other years, telephone interviews were used (Mönkediek et al., 2019).

The TwinLife longitudinal data set consists of four cohorts, and we used only the data from school-aged twins in Cohort 2 collected in the first and second waves of data collection. The school-aged twins were 11-12 years of age (N = 2,082) in the first wave and 13-15 years of age (N = 1,492) in the second wave. The first and fourth cohorts were not examined in our study as neither of them were school-agers in the first wave of data collection (they were around 5 and 23 years of age, respectively) or the second wave of data collection (around 7 and 25 years of age, respectively). Cohort 3 were school-agers in the first wave of data collection (around 17 years of age), but they were no longer school-agers in the second wave of data collection (around 19 years of age). After eliminating the twins with no information on zygosity (n = 4), our sample consisted of 842 MZ twins (male = 45.4%) and 1,240 DZ twins (male = 49.8%) who were, on average, 11 years old (i.e., M = 11.00; N = 1,876) in the first round of data collection, and 615 MZ twins (male = 46.7%) and 877 DZ twins (male = 52.1%) who were 13 years old (i.e., M = 13.02; N = 1,336) in the second round of data collection. As TwinLife only included data from same-sex DZ twins, our analyses were restricted to same-sex DZ twin pairs. According to the parents' responses on individual school-aged twins, and after eliminating nonresponses due to unclear classification or no participation, 97% of the 1,884 individual twins had grown up together to the

present day (i.e., the date on which the data were collected), 0.1% had lived separately to the present day, and 2.9% had sometimes lived separately to the present day.

Measures

For the main analyses, the children were asked to rate their perceptions of their parents' support in four dimensions (i.e., parents' expectations and structure, parents' emotional support, parents' learning encouragement, and parental control). Children also answered a question about their perceptions of their own learning motivation. For both perceived parental support and children's learning motivation measures, the students were asked to rate the extent to which each statement applied to them on a 5-point rating scale, with higher values indicating that children had higher perceptions of their parents' support and their own learning motivation.

Children's Perceptions of Parents' Expectations

Children's perceptions of their parents' expectations were assessed with three items adapted from two prior German twin studies: Cognitive ability, Self-reported Motivation and School performance (CoSMoS) and Personality And Wellbeing (TwinPaW) (Spinath & Wolf, 2006). The items were "When I study for an exam, I know exactly how much effort my parents expect of me" (1 = *not correct at all*, 5 = *completely correct*), "I know exactly what my parents expect of me in school" (1 = *not correct at all*, 5 = *completely correct*), and "When I come home with a test from class, I know beforehand if my parents will be disappointed" (1 = *not correct at all*, 5 = *completely correct*). The internal consistency of the scale ranged from $\alpha = .50$ to $\alpha = .60$ across the MZ and DZ twin groups in the two waves of data collection.

Children's Perceptions of Parents' Emotional Support

Children's perceptions of their parents' emotional support were assessed with three items adapted from the previous German twin studies, CoSMoS and TwinPaW (Spinath & Wolf, 2006). The items were "My parents console me and help me when I have problems in school" (1 = *not correct at all*, 5 = *completely correct*), "When I do not understand something in class, I can talk about it with my parents" (1 = *not correct at all*, 5 = *completely correct*), and "My parents are interested in what I have learned in school" (1 = *not correct at all*, 5 = *completely correct*). The internal consistency of the scale ranged from $\alpha = .50$ to $\alpha = .61$ across the MZ and DZ twin groups in the two waves of data collection.

Children's Perceptions of Parents' Learning Encouragement

Children's perceptions of their parents' learning encouragement were assessed with three items adapted from the previous German twin studies, CoSMoS and TwinPaW (Spinath & Wolf, 2006). The items were "When my parents help me with my studies, they encourage me to find the solution

myself" (1 = *not correct at all*, 5 = *completely correct*), "My parents explain to me that I can ask questions if I want to understand something better" (1 = *not correct at all*, 5 = *completely correct*), and "My parents encourage me to ask questions in class when I do not understand something" (1 = *not correct at all*, 5 = *completely correct*). The internal consistency of the scale ranged from α = .56 to α = .61 across the MZ and DZ twin groups in the two waves of data collection.

Children's Perceptions of Parental Control

Children's perceptions of parental control were assessed with three items adapted from the previous German twin studies, CoSMoS and TwinPaW (Spinath & Wolf, 2006). The items were "When I get a poor grade, my parents complain and demand that I work harder" (1 = *not correct at all*, 5 = *completely correct*), "When I get a poor grade, my parents threaten me with punishment (like no TV) if I do not promise to work hard in the future to improve my grades" (1 = *not correct at all*, 5 = *fully correct*), and "When I get a poor grade, my parents accuse me of thinking about too many other things and not enough about school (1 = *not correct at all*, 5 = *fully correct*). The internal consistency of the scale ranged from α = .72 to α = .78 across the MZ and DZ twin groups in the two waves of data collection.

Children's Learning Motivation

Children's learning motivation was assessed with three items adapted from the scales for learning and achievement motivation (Skalen zur Erfassung der Lern- und Leistungsmotivation: SELLMO) (Spinath et al., 2002). The items were "In school, I want to learn something interesting" (1 = *does not apply at all*, 5 = *applies completely*), "In school, I want to understand difficult things" (1 = *does not apply at all*, 5 = *applies completely*), and "In school, I want to learn as much as possible" (1 = *does not apply at all*, 5 = *applies completely*). The internal consistency of the scale ranged from α = .72 to α = .77 across the MZ and DZ twin groups in the two waves of data collection.

Zygosity

Every participant over 12 years of age rated their zygosity. For younger children between 4 and 12 years of age, their parents rated their zygosity (Lenau et al., 2017). Participants answered three questions in the three sections regarding physical similarity, being confused for the other twin, and zygosity. To assess the validity of participants' answers, researchers compared the results of an analysis of a subsample of 328 twins' genetic material (i.e., the collection of DNA using buccal swaps) with one parent's report for twins between 4 and 11 years of age (*n* = 212) or self-reports for twins between 12 and 16 years of age (*n* = 116). The classification of zygosity was successfully cross-validated as 97% of the parent reports and 96% of the self-reports were confirmed for the questionnaire (Lenau et al., 2017). The agreement rate between questionnaires and genotyping to determine zygosity was the

same or better than in other twin studies (e.g., Goldsmith, 1991; Rietveld et al., 2000; Song et al., 2010). For our analyses, zygosity was dummy-coded as 0 for MZ twins and 1 for DZ twins.

Sex

Sex was dummy-coded 0 for male twins and 1 for female twins. As TwinLife only included data from same-sex DZ twins, our analysis was restricted to same-sex DZ twin pairs.

Math and German Grades

Students had submitted photos of their latest school report cards to provide information about school grades (Mönkediek et al., 2019). However, approximately 42% of 2,082 school-aged twins in Cohort 2 did not submit the photo of their school grades, and thereby, self-reported school grades were collected for these students (Diewald, 2021; Hahn et al., 2016; Lang et al., 2020). Accordingly, we substituted self-reported school grades when the photograph of the report card was missing. Hence, in total, we had information about grades for approximately 85% of 2,082 students. Regarding the validity of the self-reported grades, previous empirical research reported a strong association between reported and actual grades for German students in different domains and grade levels (Dickhäuser & Plenter, 2005). In Germany, school grades are assigned on a scale ranging from 1 (*very good*) to 6 (*insufficient*). For ease of interpretation, we recoded the school grades so that higher values indicated higher achievement.

Personality Traits

In line with the five-factor model of personality or the NEO Personality Inventory (McCrae & Costa, 1985), five distinct dimensions of personality were identified in the TwinLife study: openness, conscientiousness, extraversion, agreeableness, and neuroticism. The five-factor model (McCrae & Costa, 1985) was used in the TwinLife study to assess personality differences on the five dimensions of personality traits. We only included openness, conscientiousness, and neuroticism as covariates in our analyses with respect to their associations with educational motivation and achievement (Komarraju & Karau, 2005). The students were asked to rate the extent to which each statement applied to them on a 7-point rating scale, with higher values indicating children's values on each personality trait.

Openness. Openness was assessed with four items adapted from the scales for the five personality traits based on the SOEP study (Gerlitz & Schupp, 2005). The items were "I see myself as someone who is original, comes up with new ideas" (1 = *does not apply at all*, 7 = *applies completely*), "I see myself as someone who values artistic, aesthetic experiences" (1 = *does not apply at all*, 7 = *applies completely*), and "I see myself as someone who has an active imagination" (1 = *does not apply at all*, 7

= *applies completely*). "I see myself as someone who is eager for knowledge" (1 = *does not apply at all*, 7 = *applies completely*).

Conscientiousness. Conscientiousness was assessed with three items adapted from the scales for the five personality traits based on the SOEP (Gerlitz & Schupp, 2005). The items were "I see myself as someone who does a thorough job" (1 = *does not apply at all*, 7 = *applies completely*), "I see myself as someone who tends to be lazy" (1 = *does not apply at all*, 7 = *applies completely*), and "I see myself as someone who does things effectively and efficiently" (1 = *does not apply at all*, 7 = *applies completely*). We recoded the second item so that a higher value indicated higher conscientiousness.

Neuroticism. Neuroticism was assessed with three items adapted from the scales for the five personality traits based on the SOEP (Gerlitz & Schupp, 2005). The items were "I see myself as someone who worries a lot" (1 = *does not apply at all*, 7 = *applies completely*), "I see myself as someone who gets nervous easily" (1 = *does not apply at all*, 7 = *applies completely*), and "I see myself as someone who is relaxed, handles stress well" (1 = d*oes not apply at all*, 7 = *applies completely*). We recoded the third item so that a higher value indicated higher neuroticism.

SES

SES was measured with the International Socio-Economic Index of Occupational Status (ISEI), which assesses an individual's occupation, income, and education with respect to the highest professional qualification they obtained. The parents were asked to classify their highest professional qualification using the 4-digit version of the International Standard Classification of Occupations-ISCO-08 classification.

Missing Data

For the twins who participated in both waves of data collection, the rate of missing data on the four dimensions of children's perceptions of parental support ranged from approximately 2.0% to 7.1% across the MZ and DZ twins in the first wave of data collection, and it ranged from approximately 1.7% to 4.4% in the second wave of data collection. For the twins who participated in both rounds of data collection, the rate of missing data on children's learning motivation ranged from approximately 1.0% to 4.5% across the MZ and DZ twins in the first wave of data collection, and it ranged from approximately 2.4% to 3.4% in the second wave. There were only four pairs of twins with missing data on zygosity across the MZ and DZ twins in the first and second waves of data collection. However, approximately 30.4% to 30.8% of the twins participated in only the first wave but did not participate in the second wave (see Table 1 for more details). The main reasons for the lower participation rate in

the second wave were nonresponse, which was attributed to a change of address or withdrawn consent. For the school-aged students, the reasons that were identified for the missing data were the nonparticipation of the twins' parents (approximately 23.6%) and the twins' own personal refusal to participate (only 0.5%).

For the covariates in the cross-lagged model, we only used the data collected in the first wave for all analyses. The rate of missing data on children's personality traits was approximately 1.3% across the MZ and DZ twins in the first wave. The rate of missing data on children's math and German grades was approximately 15% across the MZ and DZ twins in the first wave. The rate of missing data on family's SES answered by parents was approximately 9.8% across the MZ and DZ twins in the first wave. For child's biological sex, no data were missing across the MZ and DZ twins in either the first or second wave.

We handled the missing data with full information maximum likelihood estimation (FIML). This FIML approach is based on the missing-at-random (MAR) assumption and uses all available information (Baraldi & Enders, 2010; Graham, 2009).

Statistical Analyses

Beyond the common use of twin data for identifying the genetic and environmental contributions to a trait (e.g., Kovas et al., 2015), another advantage of twin data is that the familial cluster can be used to obtain quasi-experimental control over regression analyses (Turkheimer & Harden, 2014). MZ twins consist of pairs of children matched on genetic and environmental family background (Turkheimer & Harden, 2014). Thus, it is possible to measure how the differences within the pairs of twins impact their individual development, while holding constant important confounds of environmental or genetic family backgrounds (Kovas et al., 2015; Turkheimer & Harden, 2014). Accordingly, it is possible to obtain the quasi-experimental control of confounds in families when the goal is to analyze the relationship between two individual difference variables for children who grew up in the same family (Turkheimer & Harden, 2014). On the other hand, DZ twins consist of pairs of children matched on age and environmental family background, yet the extent to which they share genetic material is similar to that of nontwin siblings' genetic overlap (Plomin et al., 2001). Therefore, the analysis of DZ twins provides insights into nontwin siblings' differential educational development while holding constant age gap and birth order. A comparative analysis using data from both MZ and DZ twins allows a group comparison of the sibling pairs who differ in similarity in genetic and environmental compositions in the regression analyses (Turkheimer & Harden, 2014). Yet, rather than identifying genetic versus environmental contributions, the present study, which was conducted from a social science perspective, focused primarily on regression-based analyses of MZ and DZ twins to

identify individual differences and similarities between siblings in educational motivation and perceptions of parental support. We also conducted a comparative analysis of MZ and DZ twin data to determine perceptual differences in interpersonal similarity within twin pairs (Watzlawik, 2009) and their impact on educational development.

With regard to the nested structure of twin data, we used the robust maximum likelihood estimator (MLR) in Mplus (Muthén & Muthén, 2017) to take the non-normality of the indicator variables and the nonindependence of observations into account. The twin data included the same values twice due to the nesting of twins within twin pairs, and thereby, we defined a twin pair's family identification as a nesting/stratification variable in the model. We used the design-based correction of standard errors and fit statistics by controlling for the dependency of twin-pair-level observations (implemented with the Mplus command TYPE = COMPLEX; Stapleton et al., 2016). To obtain standardized results, we manually standardized the individual item indicators. All dimensions of parental support (i.e., parents' expectations, parents' emotional support, parents' learning encouragement, and parental control) as well as children's learning motivation and the covariates were specified as the mean of the items. We used FIML analyses to obtain the results (Graham, 2003).

For our first research question about reciprocal relationships, we applied a cross-lagged modeling approach (Kenny, 1975) and performed a multiple-group analysis in the two groups of twins (i.e., MZ and DZ). To determine whether the reciprocal effects differed between siblings within each family and between different families, we ran within-twin-pair as well as between-twin-pair regressions. We computed the within-twin-pair regression to investigate whether a child with a higher perception of parental support or a higher level of learning motivation than their twin at age 11 had a higher level of learning motivation and a higher perception of parental support 2 years later, respectively. We computed the between-twin-pair regression to investigate whether sibling pairs with a higher perception of parental support or a higher level of learning motivation than other unrelated children at age 11 had a higher level of learning motivation and a higher perception of parental support 2 years later, respectively. Accordingly, children's learning motivation measured at age 11 was predicted by the four dimensions of perceived parental support measured at age 13 for the within-twin-pair regression (i.e., the deviation of each twin from the twin-pair average) and for the between-twin-pair regression (i.e., the twin pairs' average perception; see Figure 1). By controlling for individual-level and twin-pair-level learning motivation measured at age 11, we were able to investigate whether the way parents treated their children at age 11 could predict changes in children's learning motivation at age 13 and whether the effects differed within or between twin pairs. Simultaneously, the four dimensions of perceived parental support measured at age 13 were predicted by children's learning motivation measured at age 11 for the within-twin-pair regression (i.e., the deviation of each twin from

the twin-pair average) and for the between-twin-pair regression (i.e., the twin pairs' average perception; see Figure 1). By controlling for individual-level and twin-pair-level perceived parental support measured at age 11, we were able to investigate whether the level of children's learning motivation at age 11 could predict changes in the way parents treated their children at age 13 and whether the effects differed within or between twin pairs. All regression analyses were performed separately for the MZ and DZ twin groups.

In the next step, we added individual children's characteristics of sex, personality traits, and school grades (self-reported and photographed) as well as SES as covariates to see if the reciprocal relationships between perceived parental support and learning motivation changed when the covariates were held constant for the within-twin-pair regression and the between-twin-pair regression. Consistent with the first research question, we performed a multiple-group analysis in the two groups of twins (i.e., MZ and DZ). We ran the cross-lagged regression analyses for the four dimensions of parental support (i.e., parents' expectations, parents' emotional support, parents' learning encouragement, and parental control).

Finally, we focused on differences between the MZ and DZ twins in the reciprocal associations between the four dimensions of parental support and children's learning motivation from age 11 to age 13. Simultaneously to the analyses for the first and second research questions, we used the model constraint option in Mplus to test whether the specific regression paths differed between the MZ and DZ twin pairs in the cross-lagged regression models. Specifically, we investigated whether the effect was larger for DZ than MZ twins in the four regression analyses. We investigated whether MZ and DZ twins had different paths from perceived parental support at age 11 to learning motivation at age 13 in the within-twin-pair regression and the between-twin-pair regression. We investigated whether MZ and DZ twins had different paths from learning motivation at age 11 to perceived parental support at age 13 in the within-twin-pair regression and the between-twin-pair regression. We also investigated the difference between MZ and DZ twins in the four regression paths in the cross-lagged regression models, which included the individual children's characteristics as covariates.

Table 1.

Descriptive Statistics and Correlation Matrix

Data	Measures	*N*	Miss.	*M*	SD	ICC	1	2	3	4	5	6	7	8	9
MZ	1. Parental expectation age 11	823	2.3 %	4.09	0.86	.38	1								
	2. Parental expectation age 13	598	29.0 %	4.08	0.75	.31	.25	1							
	3. Parental emotional support age 11	831	1.3 %	4.46	0.61	.31	.26	.1	1						
	4. Parental emotional support age 11	599	28.9 %	4.24	0.65	.46	.02	.21	.26	1					
	5. Parental learning encouragement age 11	830	1.4 %	4.45	0.64	.28	.27	.07	.54	.21	1				
	6. Parental learning encouragement age 13	598	29.0 %	4.37	0.62	.44	.02	.23	.19	.61	.25	1			
	7. Parental control age 11	826	1.9 %	2.35	1.08	.59	.26	.11	-.11	-.22	-.13	-.19	1		
	8. Parental control age 13	596	29.2 %	2.48	1.06	.69	.14	.19	-.12	-.24	-.09	-.2	.52	1	
	9. Learning motivation age 11	835	0.8 %	4.07	0.68	.46	.21	.06	.29	.17	.24	.13	-.09	-.07	1
	10. Learning motivation age 13	600	28.7 %	3.92	0.67	.40	.03	.17	.14	.31	.17	.31	-.1	-.12	.28
DZ	1. Parental expectation age 11	1211	2.3 %	4.05	0.86	.29	1								
	2. Parental expectation age 13	846	31.8 %	4.09	0.77	.36	.32	1							
	3. Parental emotional support age 11	1226	1.1 %	4.49	0.59	.31	.27	.11	1						
	4. Parental emotional support age 11	849	31.5 %	4.29	0.62	.33	.15	.3	.37	1					
	5. Parental learning encouragement age 11	1223	1.4 %	4.40	0.67	.23	.3	.13	.57	.3	1				
	6. Parental learning encouragement age 13	848	31.6 %	4.39	0.62	.32	.21	.35	.33	.62	.32	1			
	7. Parental control age 11	1214	2.1 %	2.31	1.04	.51	.2	.18	-.15	-.17	-.09	-.08	1		
	8. Parental control age 13	844	31.9 %	2.46	1.03	.50	.14	.27	-.12	-.14	-.12	-.03	.49	1	
	9. Learning motivation age 11	1229	0.9 %	4.02	0.66	.23	.28	.18	.31	.21	.31	.23	-.11	-.05	1
	10. Learning motivation age 13	849	31.5 %	3.85	0.71	.22	.13	.22	.13	.26	.17	.3	-.04	-.08	.31

Note. MZ = monozygotic twins, DZ = dizygotic twins, *N* = present numbers, Miss = missing data, M = mean, SD= standard deviation, ICC = Intraclass Correlation.

Results

Descriptive Statistics and Preliminary Analyses

As a preliminary analysis, we investigated the correlations among all variables separately for the samples of MZ and DZ twins (Table 1). The highest correlations between age 11 and age 13 were all reported for children's perceptions of parental control for all groups. For the correlations between the four dimensions of parental support, the correlations ranged from r = .09 to r = .62 in the total sample, from r = .02 to r = .61 in the MZ twin sample, and from r = -.08 to r = .62 in the DZ twin sample. All the highest correlations were reported between perceptions of parents' emotional support at age 11 and perceptions of parents' learning encouragement at age 13. For the correlation between perceptions of parental support at age 11 and learning motivation at age 13, the correlations ranged from r = -.06 to r = .31 in the total sample, from r = .03 to r = .31 in the MZ twin sample, and from r = -.04 to r = .26 in the DZ twin sample. F or the correlations between learning motivation at age 11 and perceptions of parental support at age 13, the correlations ranged from r = -.06 to r = .30 in the total sample, from r = .06 to r = .29 in the MZ twin sample, and from r = -.05 to r = .31 in the DZ twin sample.

Intraclass Correlations in MZ and DZ Twin Pairs

In general, the Intraclass Correlation (ICC) for learning motivation in the MZ twin pairs was ICC = .46 at age 11 and ICC = .40 at age 13, and the ICC in the DZ twin pairs was ICC = .23 and ICC = .22, which implied potentially higher similarity in learning motivation for MZ than for DZ twin pairs (Table 1). On the other hand, the ICCs for children's perceptions of parents' expectations, parents' emotional support, and parents' learning encouragement for MZ twins ranged from ICC = .28 to ICC = .44 and from ICC = .23 to ICC = .36 for DZ twins, which implied potentially a small difference between MZ and DZ twin pairs for their perceptions of their parents' support. However, for children's perceptions of parental control, the ICC for the MZ twin pairs was ICC = .59 at age 11 and ICC = .69 at age 13, whereas the ICC for the DZ twin pairs was ICC = .51 at age 11 and ICC = .50 at age 13, which implied potentially greater similarity in the children's perceptions of parental control for MZ than for DZ twins on a descriptive level.

Reciprocal Relationships Between Children's Perceptions of Their Parents' Support and Children's Learning Motivation

We analyzed whether there were reciprocal relationships between the four dimensions of perceived parental support and learning motivation that were shown to be important in the theoretical background. We computed a multiple-group analysis in the two groups of twins (i.e., MZ and DZ). We

ran the cross-lagged regression analyses with covariates for the four dimensions of parental support (i.e., parents' expectations, parents' emotional support, parents' learning encouragement, and parental control). We ran the analyses for the within-twin-pair regression as well as for the between-twin-pair regression to determine whether the reciprocal effects differed between siblings and between families. For all analyses, we controlled for the baseline influences of children's prior perceptions of parental support and learning motivation at age 11 at each child's individual level as well as the sibling pairs' average level accordingly.

In the next step, we aimed to test for effects of the individual children's characteristics on the associations between the children's perceptions of parental support and learning motivation. To do so, we added the individual children's characteristics of sex, personality traits (i.e., conscientiousness, openness, and neuroticism), and math and German grades; siblings' average personality traits and their math and German grades; and family SES as covariates to the cross-lagged models.

The results are shown in Tables 2 to 10. In general, our expectation that there would be reciprocal relationships between the children's perceptions of parental support and learning motivation was confirmed only for parents' learning encouragement in the within-twin-pair regression for DZ twins. The reciprocal relationships were held constant even after controlling for the individual children's characteristics as well as siblings' characteristics. We will now describe our results in more detail.

Children's Perceptions of Parents' Expectations and Children's Learning Motivation

Beginning with parents' expectations, children's perceptions of their parents' expectations at age 11 did not predict changes in children's learning motivation from age 11 to age 13 in the within- or between-twin-pair regressions for MZ and DZ twins, as shown in Table 2. This means that an MZ or DZ twin who had a higher perception of their parents' expectations than their sibling at age 11 did not have higher motivation at age 13 (MZ: β = 0.02, SE = 0.05, p = .748, DZ: β = -0.03, SE = 0.06, p = .576). Similarly, MZ and DZ twin pairs who had higher perceptions of their parents' expectations than other unrelated children at age 11 did not have higher motivation at age 13 (MZ: β = -0.10, SE = 0.05, p = .053, DZ: β = 0.02, SE = 0.05, p = .637). Children's learning motivation also did not serve as a statistically significant predictor of their perceptions of their parents' expectations 2 years later in the within- or between-twin-pair regressions for MZ and DZ twins. This means that MZ or DZ children who had higher learning motivation than their sibling at age 11 did not have higher perceptions of their parents' expectations at age 13 (MZ: β = -0.05, SE = 0.06, p = .456, DZ: β = 0.05, SE = 0.04, p = .238). Similarly, the pairs who had higher learning motivation than other unrelated children at age 11 did not have

higher perceptions of their parents' expectations at age 13 (MZ: β = -0.10, SE = 0.06, *p* = .090, DZ: β = 0.07, SE = 0.05, *p* = .172).

Table 2.
Cross-lagged Model of the Perceived Parental Expectation and Learning Motivation Across Age 11 and Age 13.

	MZ						DZ					
	Learning motivation age 13			Parental expectation age 13			Learning motivation age 13			Parental expectation age 13		
	β	SE	*P*	β	SE	*P*	β	SE	*P*	β	SE	*P*
Parental expectation within-pair age 11	0.02	0.05	0.748	0.20	0.05	<.001	-0.03	0.06	0.576	0.16	0.05	0.002
Parental expectation pair-average age 11	-0.10	0.05	0.053	0.37	0.07	<.001	0.02	0.05	0.637	0.39	0.05	<0.001
Learning motivation within-pair age 11	0.15	0.06	0.009	-0.05	0.06	0.456	0.27	0.05	<0.001	0.05	0.04	0.238
Learning motivation Pair-average age 11	0.32	0.06	<0.001	-0.10	0.06	0.090	0.36	0.05	<0.001	0.07	0.05	0.172

Note. MZ = monozygotic twins, DZ = dizygotic twins. p = two-tailed p-value. β = Standardized parameter estimates.

Controlling for the characteristics of individual children, sibling characteristics, and family SES, most of the nonsignificant reciprocal associations between children's perceptions of their parents' expectations and children's learning motivation from age 11 to age 13 remained constant as can be seen in Table 3. On the other hand, the relationship between children's learning motivation at age 11 and their perceptions of their parents' expectations at age 13 became negative and significant only in the within-twin-pair regression for MZ twins (β = -0.13, SE = 0.07, *p* = .045). This means that MZ twin pairs who had higher learning motivation than other unrelated children at age 11 had lower perceptions of their parents' expectations at age 13 after accounting for the characteristics of individual children, sibling characteristics, and family SES. The substantial change in the association indicates that the added covariates are related to the effect of sibling pairs' learning motivation on their perceptions of their parents' expectations.

Table 3.

Cross-lagged Model of the Perception of the Parental Expectation and Learning Motivation Across Age 11 and Age 13 with Covariates.

	MZ						DZ					
	Learning motivation age 13			Parental expectation age 13			Learning motivation age 13			Parental expectation age 13		
	β	SE	*P*	β	SE	*P*	β	SE	*P*	β	SE	*P*
Parental expectation within-pair age 11	0.002	0.04	0.958	0.21	0.06	<0.001	-0.02	0.05	0.693	0.16	0.05	0.002
Parental expectation pair average age 11	-0.06	0.05	0.247	0.38	0.06	<0.001	0.03	0.05	0.587	0.39	0.05	<0.001
Learning motivation within-pair age 11	0.11	0.06	0.061	-0.06	0.05	0.315	0.22	0.05	<0.001	0.05	0.05	0.229
Learning motivation pair average age 11	0.16	0.06	0.012	-0.13	0.07	0.045	0.25	0.06	<0.001	0.07	0.06	0.224
Sex	0.16	0.09	0.100	-0.04	0.10	0.647	0.03	0.08	0.695	-0.14	0.08	0.104
SES	-0.01	0.05	0.833	0.12	0.05	0.017	-0.05	0.04	0.247	-0.01	0.04	0.886
Conscientiousness within-pair age 11	0.10	0.05	0.070	-0.09	0.06	0.120	0.05	0.05	0.266	-0.01	0.04	0.866
Openness within-pair age 11	0.05	0.05	0.380	0.10	0.06	0.103	0.12	0.05	0.017	0.01	0.05	0.886
Neuroticism within-pair age 11	-0.05	0.05	0.380	0.04	0.05	0.511	0.02	0.05	0.618	0.04	0.04	0.343
Conscientiousness pair average age 11	0.18	0.06	0.005	0.03	0.07	0.684	0.08	0.06	0.238	-0.01	0.07	0.867
Openness pair average age 11	0.19	0.06	0.001	0.05	0.06	0.397	0.16	0.06	0.008	0.01	0.06	0.800
Neuroticism pair average age 11	0.012	0.06	0.845	0.004	0.06	0.947	-0.03	0.05	0.532	0.01	0.06	0.877
Math grade within-pair age 11	0.10	0.08	0.201	0.15	0.08	0.077	0.03	0.08	0.664	-0.02	0.07	0.817
German grade within-pair age 11	-0.10	0.09	0.295	0.06	0.10	0.565	0.02	0.07	0.749	-0.07	0.06	0.292
Math grade pair average age 11	-0.01	0.07	0.877	0.023	0.07	0.754	0.01	0.07	0.915	-0.01	0.07	0.905
German grade pair average age 11	0.08	0.07	0.250	-0.07	0.08	0.383	0.02	0.06	0.755	0.02	0.06	0.776

Note. MZ = monozygotic twins, DZ = dizygotic twins. p = two-tailed p-value. β = Standardized parameter estimates. SES = Socio-economic status.

For the effects of individual children's and siblings' characteristics (Table 3), MZ twin pairs who had higher levels of conscientiousness and openness than other unrelated children at age 11 reported higher learning motivation at age 13 (twin pairs' average conscientiousness: β = 0.18, SE = 0.06, *p* = .005, twin pairs' average openness: β = 0.19, SE = 0.06, *p* = .001). For DZ twins, a child who had a higher level of openness than their sibling at age 11 and the sibling pair who had a higher level of openness than other unrelated children at age 11 had higher learning motivation at age 13 (within-pair openness: β = 0.12, SE = 0.05, *p* = .017, twin pairs' average openness: β = 0.16, SE = 0.06, *p* = .008).

Children's Perceptions of Their Parents' Emotional Support and Children's Learning Motivation

As can be seen in Table 4, children's perceptions of their parents' emotional support at age 11 did not predict changes in children's learning motivation from age 11 to age 13 in the within- or between-twin-pair regressions for MZ and DZ twins. Whether a child who had higher perceptions of their parents' emotional support than their siblings or sibling pairs who experienced higher parental emotional support than other unrelated children at age 11 did not have higher learning motivation 2 years later. On the other hand, there was a statistically significant prediction of the change in children's perceptions of their parents' emotional support at age 13 by children's learning motivation at age 11 only in the within-twin-pair regression for DZ twins (β = 0.14, SE = 0.04, *p* = .005) and only in the between-twin-pair regression for MZ twins (β = 0.12, SE = 0.06, *p* = .046). This means that a DZ twin who had higher learning motivation than their twin at age 11 had an increase in their perception of their parents' emotional support at age 13. MZ twin pairs who had higher learning motivation than other unrelated children at age 11 had higher perceptions of their parents' emotional support at age 13.

Table 4.
Cross-lagged Model of the Perceived Parental Emotional Support and Learning Motivation Across Age 11 and Age 13.

	MZ						DZ					
	Learning motivation age 13			Parental emotional support age 13			Learning motivation age 13			Parental emotional support age 13		
	β	SE	*P*	β	SE	*P*	β	SE	*P*	β	SE	*P*
Parental emotional support within-pair age 11	0.04	0.06	0.472	0.03	0.06	0.612	0.09	0.06	0.123	0.16	0.05	0.003
Parental emotional support pair-average age 11	0.07	0.06	0.263	0.33	0.07	<0.001	0.01	0.05	0.844	0.42	0.05	<0.001
Learning motivation within-pair age 11	0.14	0.06	0.012	0.000	0.06	0.998	0.25	0.05	<0.001	0.14	0.05	0.005
Learning motivation Pair-average age 11	0.28	0.06	<0.001	0.12	0.06	0.046	0.36	0.05	<0.001	0.08	0.05	0.117

Note. MZ = monozygotic twins, DZ = dizygotic twins. p = two-tailed p-value. β = Standardized parameter estimates.

When we controlled for the individual children's characteristics, siblings' characteristics, and families' SES, the positive significant association between children's learning motivation at age 11 and their perceptions of their parents' emotional support at age 13 became nonsignificant in the between-twin-pair regression for MZ twins (β = -0.05, SE = 0.07, *p* = .469). When the individual children's and siblings' characteristics were considered, MZ twin pairs who had higher levels of learning motivation than other unrelated children at age 11 no longer perceived their parents' emotional support at age 13. On the other hand, DZ twins who had higher learning motivation than their sibling at age 11 still robustly showed higher perceptions of their parents' emotional support at age 13 despite the addition of the covariates (β = 0.11, SE = 0.05, *p* = .037). See Table 5 for all the other nonsignificant effects that remained constant even when the covariates were added.

Table 5.

Cross-lagged Model of the Perception of the Parental Emotional Support and Learning Motivation Across Age 11 and Age 13 with Covariates.

	MZ						DZ					
	Learning motivation age 13			Parental emotional support age 13			Learning motivation age 13			Parental emotional support age 13		
	β	SE	*P*	β	SE	*P*	β	SE	*P*	β	SE	*P*
Perception of parent within-pair age 11	0.02	0.06	0.696	0.03	0.06	0.604	0.08	0.06	0.166	0.14	0.05	<0.001
Perception of parent pair average age 11	0.06	0.05	0.310	0.32	0.07	<0.001	-0.01	0.05	0.821	0.40	0.05	0.008
Learning motivation within-pair age 11	0.11	0.06	0.069	0.02	0.06	0.753	0.20	0.05	<0.001	0.11	0.05	0.037
Learning motivation pair average age 11	0.12	0.07	0.061	-0.05	0.07	0.469	0.26	0.06	<0.001	0.05	0.06	0.399
Sex	0.15	0.09	0.111	0.18	0.11	0.081	0.03	0.08	0.715	0.05	0.08	0.551
SES	-0.001	0.05	0.979	0.17	0.05	<0.001	-0.05	0.04	0.240	0.09	0.04	0.025
Conscientiousness within-pair age 11	0.10	0.06	0.066	-0.12	0.06	0.028	0.05	0.05	0.310	0.06	0.04	0.132
Openness within-pair age 11	0.04	0.05	0.413	0.05	0.05	0.333	0.11	0.05	0.020	0.10	0.04	0.013
Neuroticism within-pair age 11	-0.04	0.05	0.411	-0.03	0.06	0.571	0.02	0.05	0.688	-0.01	0.04	0.850
Conscientiousness pair average age 11	0.19	0.06	0.004	0.32	0.07	<0.001	0.08	0.06	0.228	0.04	0.06	0.538
Openness pair average age 11	0.19	0.06	0.001	0.03	0.07	0.736	0.16	0.06	0.008	0.06	0.05	0.255
Neuroticism pair average age 11	0.01	0.06	0.888	0.06	0.06	0.322	-0.03	0.05	0.534	-0.6	0.05	0.207
Math grade within-pair age 11	0.10	0.08	0.209	0.01	0.07	0.930	0.05	0.08	0.556	-0.01	0.07	0.846
German grade within-pair age 11	-0.10	0.09	0.306	-0.02	0.09	0.824	0.02	0.07	0.739	-0.10	0.06	0.096
Math grade pair average age 11	-0.1	0.07	0.845	-0.03	0.09	0.704	0.001	0.07	0.988	-0.003	0.06	0.963
German grade pair average age 11	0.09	0.07	0.216	0.07	0.09	0.400	0.02	0.06	0.752	-0.04	0.06	0.543

Note. MZ = monozygotic twins, DZ = dizygotic twins. p = two-tailed p-value. β = Standardized parameter estimates. SES = Socio-economic status.

Regarding the effects of the individual children's and siblings' characteristics (Table 5), an MZ twin who had a higher level of conscientiousness than their sibling at age 11 had lower perceptions of their parents' emotional support at age 13 (β = -0.12, SE = 0.06, *p* = .028). By contrast, MZ twin pairs who had higher levels of conscientiousness than other unrelated children at age 11 had higher perceptions of their parents' emotional support (β = 0.32, SE = 0.07, *p* < .001) as well as higher learning motivation (β = 0.19, SE = 0.06, *p* = .004) at age 13. For DZ twins, a child who had a higher level of openness than their sibling at age 11 had higher learning motivation (β = 0.11, SE = 0.05, *p* = .020) and higher perceptions of their parents' emotional support at age 13. MZ and DZ twin pairs who had higher levels of openness than other unrelated children at age 11 had higher learning motivation at age 13 (MZ: β = 0.19, SE = 0.06, *p* = .001, DZ: β = 0.16, SE = 0.06, *p* = .008). The paths from SES to the children's perceptions of their parents' emotional support at age 13 were positive and significant for both MZ (β = 0.17, SE = 0.05, *p* < .001) and DZ twins (β = 0.09, SE = 0.04, *p* = .025).

Table 6.
Cross-lagged Model of the Perceived Parental Learning Encouragement and Learning Motivation Across Age 11 and Age 13.

	MZ						DZ					
	Learning motivation age 13			Parental Learning Encouragement age 13			Learning motivation age 13			Parental Learning Encouragement age 13		
	β	SE	*P*	β	SE	*P*	β	SE	*P*	β	SE	*P*
Parental Learning Encouragement within-pair age 11	0.09	0.06	0.111	0.11	0.06	0.044	0.14	0.05	0.006	0.18	0.05	0.001
Parental Learning Encouragement pair-average age 11	0.13	0.06	0.039	0.30	0.07	<0.001	0.04	0.05	0.402	0.32	0.06	<0.001
Learning motivation within-pair age 11	0.14	0.06	0.011	-0.03	0.06	0.573	0.23	0.05	<0.001	0.18	0.05	<0.001
Learning motivation Pair-average age 11	0.27	0.06	<0.001	0.10	0.06	0.123	0.35	0.05	<0.001	0.13	0.05	0.016

Note. MZ = monozygotic twins, DZ = dizygotic twins. p = two-tailed p-value. β = Standardized parameter estimates.

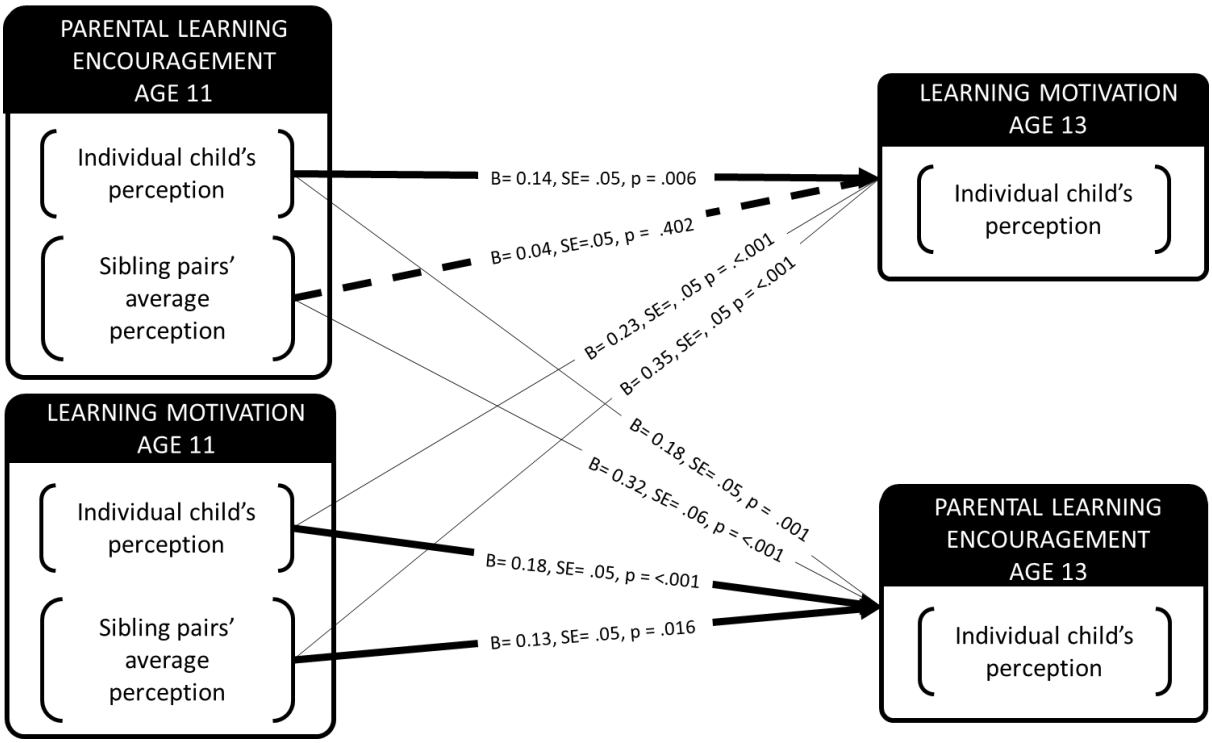
Children's Perceptions of Their Parents' Learning Encouragement and Children's Learning Motivation

A reciprocal relationship was observed for the children's perceptions of their parents' learning encouragement and children's learning motivation only in the within-twin-pair regression for DZ twins (Table 6): Not only did a DZ twin's higher perception of their parents' learning encouragement than their sibling at age 11 predict their learning motivation 2 years later (β = 0.14, SE = 0.06, *p* = .05), but their higher level of learning motivation than their sibling at age 11 also predicted the child's higher perception of their parents' learning encouragement 2 years later (β = 0.18, SE = 0.05, *p* < .001) as

shown in Figure 2. As for the DZ twins' between-twin-pair regression, the change in the children's perceptions of their parents' learning encouragement from age 11 to age 13 was predicted by their learning motivation at age 11 (β = 0.13, SE = 0.05, *p* = .016), but the opposite effect was not found. This means that DZ twin pairs who had higher learning motivation than other unrelated children at age 11 tended to have higher perceptions of their parents' learning encouragement at age 13. On the other hand, MZ twins showed a statistically significant relationship between children's learning motivation at age 11 and their perceptions of their parents' learning encouragement 2 years later (β = 0.13, SE = 0.06, *p* = .039) only in the between-twin-pair regression. This means that MZ twin pairs who had higher perceptions of their parents' learning encouragement than other unrelated children at age 13 had higher learning motivation at age 13. For the results of the nonsignificant relationships, see Table 6 for more details.

Figure 2

Result of the Reciprocal Relations Between the Perceived Parental Learning Encouragement and DZ twins' Learning Motivation Across Age 11 and Age 13.



The reciprocal effects between children's perceptions of their parents' learning encouragement and the children's learning motivation across the 2 years from age 11 to age 13 remained significant when holding the individual children's characteristics, siblings' characteristics, and families' SES constant as can be seen in Table 7. However, the change appeared in the previously

significant association between children's perceptions of their parents' learning encouragement at age 11 and the children's learning motivation at age 13 in the between-twin-pair regression for MZ twins that became nonsignificant (β = 0.08, SE = 0.06, *p* = .142). The change also appeared in the previously significant association between children's learning motivation at age 11 and their perceptions of their parents' learning encouragement at age 13 in the between-twin-pair regression for DZ twins that became nonsignificant (β = 0.08, SE = 0.06, *p* = .186). This means that previously significant associations were related to the individual children's characteristics, siblings' characteristics, and families' SES.

For the effects of the individual children's and siblings' characteristics shown in Table 7, MZ twin pairs who had higher levels of conscientiousness and openness than other unrelated children had higher learning motivation at age 13. MZ twin pairs' higher levels of conscientiousness than other unrelated children at age 11 further had an influence on their perceptions of their parents' learning encouragement after 2 years. Unexpectedly, an MZ child who had a higher German grade than their sibling at age 11 had lower perceptions of their parents' learning encouragement at age 13 (β = -0.24, SE = 0.12, *p* = .042). Female MZ twins tended to have higher perceptions of their parents' learning encouragement than male twins (β = 0.26, SE = 0.10, *p* = .013). DZ twins reported higher learning motivation at age 13 when a child had a higher level of openness than their sibling (β = 0.11, SE = 0.05, *p* = .022) and when the sibling pairs had higher levels of openness than other unrelated children (β = 0.16, SE = 0.06, *p* = .009) at age 11. In addition, a DZ twin who had a higher level of conscientiousness than their sibling at age 11 had a higher perception of their parents' learning encouragement at age 13 (β = 0.10, SE = 0.04, *p* = .013). Yet, DZ twin pairs who had higher levels of neuroticism than other unrelated children at age 11 had lower perceptions of their parents' learning encouragement at age 13 (β = -0.12, SE = 0.05, *p* = .027)

Table 7.

Cross-lagged Model of the Perceived Parental Learning Encouragement and Learning Motivation Across Age 11 and Age 13 with Covariates.

	MZ						DZ					
	Learning motivation age 13			Parental learning encouragement age 13			Learning motivation age 13			Parental learning encouragement age 13		
	β	SE	*P*	β	SE	*P*	β	SE	*P*	β	SE	*P*
Parental learning encouragement within-pair age 11	0.08	0.05	0.153	0.11	0.05	0.036	0.13	0.05	0.011	0.17	0.05	0.002
Parental learning encouragement pair average age 11	0.08	0.06	0.142	0.24	0.07	<0.001	0.03	0.05	0.595	0.30	0.06	<0.001
Learning motivation within-pair age 11	0.11	0.06	0.058	-0.02	0.06	0.699	0.18	0.05	0.001	0.16	0.06	0.001
Learning motivation pair average age 11	0.12	0.07	0.068	0.01	0.07	0.942	0.25	0.06	0.000	0.08	0.06	0.186
Sex	0.14	0.09	0.144	0.26	0.10	0.013	0.03	0.08	0.735	0.04	0.08	0.666
SES	-0.01	0.05	0.886	0.08	0.05	0.124	-0.05	0.04	0.250	-0.05	0.04	0.263
Conscientiousness within-pair age 11	0.10	0.05	0.066	-0.07	0.05	0.207	0.04	0.05	0.392	0.10	0.04	0.013
Openness within-pair age 11	0.03	0.05	0.538	0.09	0.05	0.071	0.11	0.05	0.022	0.01	0.05	0.787
Neuroticism within-pair age 11	-0.04	0.05	0.408	-0.08	0.06	0.177	0.01	0.05	0.842	0.03	0.04	0.491
Conscientiousness pair average age 11	0.18	0.06	0.004	0.20	0.07	0.004	0.07	0.06	0.250	0.03	0.06	0.654
Openness pair average age 11	0.19	0.06	0.001	0.000	0.07	0.995	0.16	0.06	0.009	0.10	0.05	0.048
Neuroticism pair average age 11	0.01	0.06	0.913	0.01	0.05	0.863	-0.03	0.05	0.547	-0.12	0.05	0.027
Math grade within-pair age 11	0.09	0.08	0.241	-0.13	0.08	0.088	0.05	0.08	0.501	0.04	0.06	0.554
German grade within-pair age 11	-0.10	0.09	0.298	-0.24	0.12	0.042	0.02	0.07	0.743	-0.05	0.07	0.508
Math grade pair average age 11	-0.01	0.07	0.854	0.01	0.08	0.956	0.01	0.07	0.921	0.01	0.06	0.808
German grade pair average age 11	0.09	0.07	0.214	0.03	0.07	0.670	0.02	0.06	0.775	-0.07	0.06	0.229

Note. MZ = monozygotic twins, DZ = dizygotic twins. *p* = two-tailed *p*-value. β = Standardized parameter estimates. SES = Socio-economic status.

Children's Perceptions of Parental Control and Children's Learning Motivation

The reciprocal relationship was not observed for parental control and children's learning motivation in the within- and between-twin-pair regressions for both MZ and DZ twins as shown in Table 8. Neither a child's nor a sibling pairs' perceptions of their parents' emotional support at age 11 predicted the children's learning motivation 2 years later. Also, neither the child's nor a sibling pairs' learning motivation at age 11 predicted an increase in their perceptions of their parents' emotional support 2 years later. In other words, a child who reported higher parental control or learning motivation than their sibling did not have higher learning motivation (MZ: β = -0.03, SE = 0.06, *p* = .657, DZ: β = -0.06, SE = 0.07, *p* = .343) or report higher parental control (MZ: β = 0.07, SE = 0.05, *p* = 0.165, DZ: β = -0.01, SE = 0.04, *p* = 0.728) 2 years later, respectively. And the sibling pairs who experienced higher parental control or had higher learning motivation than other unrelated children at age 11 did not have higher learning motivation (MZ: β = -0.08, SE = 0.05, *p* = .111, DZ: β = 0.01, SE = 0.05, *p* = .838) or report higher parental control (MZ: β = -0.05, SE = 0.05, *p* = .279, DZ: β = 0.004, SE = 0.05, *p* = .941) 2 years later, respectively. Simply put, there were no significant relationships between children's perceptions of parental control and children's learning motivation.

Table 8.
Cross-lagged Model of the Perceived Parental Control and Learning Motivation Across Age 11 and Age 13.

	MZ						DZ					
	Learning motivation age 13			Parental control age 13			Learning motivation age 13			Parental control age 13		
	β	SE	*P*	β	SE	*P*	β	SE	*P*	β	SE	*P*
Parental control within-pair age 11	-0.03	0.06	0.657	0.05	0.06	0.350	-0.06	0.07	0.343	0.20	0.05	<0.001
Parental control pair-average age 11	-0.08	0.05	0.111	0.61	0.05	<0.001	0.01	0.05	0.838	0.58	0.04	<0.001
Learning motivation within-pair age 11	0.15	0.06	0.009	0.07	0.05	0.165	0.26	0.05	<0.001	-0.01	0.04	0.728
Learning motivation Pair-average age 11	0.30	0.06	<0.001	-0.05	0.05	0.279	0.36	0.05	<0.001	0.004	0.05	0.941

Note. MZ = monozygotic twins, DZ = dizygotic twins. p = two-tailed p-value. β = Standardized parameter estimates.

After controlling for individual children's characteristics, siblings' characteristics, and families' SES, all of the nonsignificant reciprocal associations between children's perceptions of parental control and children's learning motivation from age 11 to age 13 remained constant as can be seen in Table 9.

For the effects of the individual children's and siblings' characteristics, the MZ twin pairs who had higher levels of conscientiousness and openness than other unrelated children at age 11 had higher learning motivation at age 13 (twin pairs' average conscientiousness: β = 0.19, SE = 0.07, *p* = .004; twin pairs' average openness: β = 0.19, SE = 0.06, *p* = .001). Interestingly, an MZ child who had a higher math grade than their sibling had a higher perception of parental control at age 13 (β = 0.16, SE = 0.07, *p* = .021). For DZ twins, a child who had a higher level of openness than their sibling at age 11 and the sibling pair who had higher levels of openness than other unrelated children at age 11 had higher learning motivation at age 13 (within-twin-pair regression: β = 0.12, SE = 0.05, *p* = .017, between-twin-pair regression: β = 0.16, SE = 0.0, p = .008). For both MZ and DZ twins, female twins tended to have lower perceptions of parental control than male twins at age 13 as shown in Table 9.

Table 9.

Cross-lagged Model of the Perception of the Parental Control and Learning Motivation Across Age 11 and Age 13 with Covariates.

	MZ						DZ					
	Learning motivation age 13			Parental control age 13			Learning motivation age 13			Parental control age 13		
	β	SE	*P*	β	SE	*P*	β	SE	*P*	β	SE	*P*
Parental control within-pair age 11	-0.03	0.06	0.667	0.06	0.06	0.254	-0.04	0.07	0.512	0.18	0.05	0.001
Parental control pair average age 11	-0.003	0.05	0.951	0.53	0.05	<0.001	0.04	0.05	0.478	0.52	0.04	<0.001
Learning motivation within-pair age 11	0.11	0.06	0.06	0.05	0.05	0.274	0.21	0.05	<0.001	0.01	0.04	0.8831
Learning motivation pair average age 11	0.14	0.06	0.025	0.01	0.06	0.902	0.25	0.06	<0.001	0.03	0.06	0.599
Sex	0.16	0.10	0.100	-0.39	0.10	<0.001	0.04	0.09	0.631	-0.38	0.07	<0.001
SES	-0.01	0.05	0.906	0.04	0.05	0.414	-0.05	0.04	0.278	-0.04	0.04	0.284
Conscientiousness within-pair age 11	0.10	0.06	0.069	-0.05	0.05	0.275	0.05	0.05	0.259	-0.08	0.04	0.062
Openness within-pair age 11	0.04	0.05	0.397	0.04	0.05	0.380	0.12	0.05	0.021	-0.02	0.04	0.575
Neuroticism within-pair age 11	-0.04	0.05	0.390	-0.07	0.04	0.091	0.02	0.05	0.614	0.07	0.04	0.053
Conscientiousness pair average age 11	0.19	0.07	0.004	0.000	0.06	0.994	0.08	0.06	0.203	-0.11	0.06	0.061
Openness pair average age 11	0.19	0.06	0.001	-0.07	0.07	0.276	0.16	0.06	0.007	0.05	0.05	0.294
Neuroticism pair average age 11	0.01	0.06	0.888	0.04	0.06	0.479	-0.04	0.06	0.470	-0.02	0.05	0.662
Math grade within-pair age 11	0.10	0.08	0.209	0.16	0.07	0.021	0.04	0.08	0.650	0.01	0.06	0.889
German grade within-pair age 11	-0.10	0.10	0.274	-0.01	0.06	0.840	0.02	0.07	0.760	-0.04	0.06	0.538
Math grade pair average age 11	-0.01	0.07	0.907	-0.05	0.07	0.417	0.01	0.07	0.871	0.000	0.05	0.997
German grade pair average age 11	0.08	0.07	0.230	-0.06	0.07	0.369	0.02	0.06	0.772	-0.02	0.05	0.662

Note. MZ = monozygotic twins, DZ = dizygotic twins. *p* = two-tailed *p*-value. β = Standardized parameter estimates. SES = Socio-economic status.

Differences Between MZ and DZ Twins

By running the analyses for the first and second research questions simultaneously, we aimed to determine whether there were differences between MZ and DZ twins in the reciprocal effects between the four dimensions of parents' support and children's learning motivation from age 11 to age 13 in the within-twin-pair regression as well as in the between-twin-pair regression (Table 10). Hypothesizing a potential effect of sibling similarity on the reciprocal influences between parents and children, we aimed to investigate whether MZ and DZ twins would differ in reciprocal associations when comparing one twin with their co-twin and when comparing a twin pair with other unrelated children. Beyond our previous explanations at the descriptive level, we explicitly compared the regression coefficients for the MZ and DZ twins. In general, our expectation that MZ and DZ twins would differ in the reciprocal relationships between the children's perceptions of their parents' support and the children's learning motivation was not confirmed but was only confirmed for the effect of children's learning motivation at age 11 on their perception of their parents' learning encouragement 2 years later in the within-twin-pair regression.

When we explicitly compared the four coefficients between the MZ and DZ twins using model constraints for each dimension of parental support (see Table 10), the requisite model constraints showed that the regression paths from three of the dimensions of children's perceptions of parental support (i.e., parents' expectations, parents' emotional support, and parental control) at age 11 to an individual child's learning motivation at age 13 did not differ between MZ and DZ twins in the within-twin-pair regression, and the paths did not differ between MZ and DZ twins in the between-twin-pair regression. The regression paths from the individual children's learning motivation at age 11 to the same three dimensions of children's perceptions of parental support (i.e., parents' expectations, parents' emotional support, and parental control) at age 13 also did not differ between MZ and DZ twins in the within-twin-pair regression, and the paths did not differ for MZ and DZ twins in the between-twin-pair regression. In addition, the requisite model constraints showed that MZ and DZ twins also did not differ in any the regression paths in the reciprocal associations between the same three dimensions of children's perceptions of parental support (i.e., parents' expectations, parents' emotional support, and parental control) and children's learning motivation from age 11 to age 13 when the covariates of individual children's characteristics, siblings' characteristics, and families' SES were included in the model (see Table 10).

Therefore, only the regression path from the individual children's learning motivation at age 11 to their perceptions of their parents' learning encouragement at age 13 differed between the MZ and DZ twins in the within-twin-pair regression ($\beta = 0.22$, SE = 0.07, $p = .004$) as shown in Table 10. This means that a DZ child who had higher learning motivation than their sibling at age 11 was more likely

to perceive higher learning encouragement from their parents than an MZ twin. Consistently, the requisite model constraints showed that MZ and DZ twins also differed only in the regression path from an individual child's learning motivation at age 11 to their perception of their parents' learning encouragement at age 13 when the covariates of individual children's characteristics, siblings' characteristics, and families' SES (β = 0.22, SE = 0.07, *p* = .004) were included, as can be seen in Table 7. MZ and DZ twins did not differ in any other regression paths. For more details, see Tables 10.

Table 10.

Regression Path Difference in the Cross-lagged Model with Covariates.

	Path differences. MZ vs. DZ											
	Parental expectation			Parental emotional support			Parental learning encouragement			Parental control		
Regression path	β	SE	*P*	β	SE	*P*	β	SE	*P*	β	SE	*P*
Perceived parental support within-pair age 11 -Learning motivation age 13	-.02	.07	.733	.05	.08	.519	.05	.07	.512	-.02	.09	.841
Perceived parental support pair average age 11- Learning motivation age 13	-.02	.06	.811	-.04	.08	.567	.03	.07	.682	-.10	.07	.109
Learning motivation within-pair age 11- Perception of parent age 13	.11	.08	.126	.09	.08	.257	.18	.08	.021	-.05	.07	.491
Learning motivation pair average age 11- Perception of parent age 13	-.13	.08	.117	-.13	.08	.117	-.13	.08	.117	-.13	.08	.117

Note. MZ = monozygotic twins, DZ = dizygotic twins. p = Two-tailed p-value. β= Standardized parameter estimates.

Discussion

With our first research question, we investigated whether there were reciprocal relationships between parental support and children's learning motivation. We examined whether the reciprocal relationships differed between siblings and between families. We did indeed find reciprocal relationships between children's perceptions of their parents' learning encouragement and children's learning motivation from age 11 to age 13. The reciprocal relationship differed between siblings but only for DZ twins. Yet we did not find such an effect for children's perceptions of their parents' expectations, parents' emotional support, or parental control. With our second research question, we added children's characteristics and families' SES to see if the added covariates were related to the reciprocal association between children's perceptions of parental support and children's learning motivation. The reciprocal relationships between the children's perceptions of their parents' learning encouragement and the children's learning motivation in the within-twin-pair regression for DZ twins remained robust against the added covariates. Yet, children's personality traits, school grades, and biological sex were related to the diverse dimensions of parental support as well as to the children's learning motivation. With our third research question, we investigated whether the reciprocal relationships differed between the MZ and DZ twins regarding the relative similarity between siblings. The reciprocal effects between children's learning motivation and their perceptions of their parents' learning encouragement was substantially larger for DZ than for MZ twins. In the following, we discuss our findings in more depth.

Reciprocal Association Between Individual Children's Learning Motivation and Their Perceptions of Their Parents' Learning Encouragement

Based on expectancy-value theory's model of family influences (Eccles, 2007), we hypothesized a reciprocal relationship between each child's learning motivation and the child's perception of a parent's child-specific support. We found support for our hypothesis that not only would each child's perception of a parent's learning encouragement at age 11 predict their learning motivation 2 years later, but the child's level of motivation at age 11 would also predict the child's perception of a parent's learning encouragement 2 years later. Each child's learning motivation and the child's perception of a parent's learning encouragement mutually reinforced one another, which shaped children's educational development throughout the 2 years. We found the consistent reciprocal association even after holding individual children's sex, personality traits, school grades, and family SES constant. The current result is comparable to and is in line with previous studies that reported reciprocal influences between parental involvement and expectations on the one side and children's achievement and academic functioning on the other (Briley et al., 2014; Dumont et al., 2014). Along with the prior findings, the present findings contribute to the evidence for transactional theories (Kuczynski & Parkin,

2007; Sameroff, 2009), which propose a bidirectional interactive learning process that incorporates the influences of both children and parents.

Importantly, our findings further showed that the reciprocal relationships differed between siblings. This adds new insights to diversified parental support and differentiated learning motivation between siblings in the transition between age 11 and age 13. Whereas most studies have collected data from one child and one parent per family to represent general parenting behavior and support and have compared one family with another (for a review and a meta-analysis, see Boonk et al., 2018; Jeynes, 2003), our findings shift the focus to within-family differences in motivational dynamics. A parent's child-specific learning encouragement and each child's learning motivation reciprocally reinforced each other to create an individualized learning environment for each sibling in the family as hypothesized in expectancy-value theory's model of family influences (Eccles, 2007) and in the transactional model framework (Bell, 1968; Kuczynski & Parkin, 2007; Sameroff, 1994, 2009). The present findings also correspond to the previous empirical finding that sibling differences in characteristics create a differential experience for each child within the same family (Asbury et al., 2003; Daniels & Plomin, 1985; Dunn & Plomin, 1990; Plomin & Daniels, 2011), which in turn differentiates individual siblings' educational development and their motivation (Kovas et al., 2015; Plomin & Daniels, 2011; Rowe & Plomin, 1981).

However, it is noteworthy that this reciprocal relationship was reported only for DZ twins but not for MZ twins. In other words, only the sibling pairs who moderately resembled each other perceived differences in their interactions with their parents, whereas the very similar sibling pairs did not perceive differences in their interactions with their parents. MZ and DZ twins especially differed in the effect of a sibling's relative learning motivation on their perceptions of their parents' learning encouragement. It could be that DZ twins differed in their learning motivation more than MZ twins (see the ICC and correlation in Table 1), and thereby, they were treated more differently by their parents. Given that DZ twins' genetic overlap is similar to that of nontwin siblings (Plomin et al., 2001), the reciprocal effects found in DZ twins imply that nontwin siblings may have the same kinds of individualized interactions with their parents. Yet the significant difference between DZ twins and MZ twins points to the role that perceived sibling resemblance plays in how parents and siblings interact in the learning situation. This finding is in line with the social comparison theory (Festinger, 1954) viewpoint that perceived interpersonal similarity differentiates social comparisons among individuals. Thus, the current finding of differential perceptions of parental support within less similar sibling pairs implies that parents' social comparisons of sibling differences had an impact on parents' differential treatment of the siblings.

Dimensions of Parental Support and Their Differential Effects

Given that the reciprocal relationship with children's learning motivation was reported only for parents' learning encouragement, the dimensions of parental support also mattered for the reciprocal effects. Specifically, the reciprocal effects were not found for parents' expectations, parents' emotional support, or parental control in our study. Parents' expectations represent a double-edged sword that, on the one hand, could promote the sharing of the extent to which an education is valued between the child and parent, but on the other hand, it could negatively affect children's motivation by making them feel the pressure of their parents' standards (Jeynes, 2011). In our study, parents' expectations were measured by asking children about their awareness of their parents' expectation standards in exam situations and in the school context, and thereby, parents' expectations represented more of a parental standard than a general agreement about the value of an education between the children and parents. Accordingly, parents' expectations did not have an impact on children's learning motivation, nor was it influenced by children's learning motivation in the current findings. Moreover, when we held children's individual characteristics, siblings' characteristics, and families' SES constant, MZ twin pairs who had higher learning motivation than other unrelated children at age 11 had lower perceptions of their parents' expectations at age 13. Based on previous studies (Jeynes, 2011), this could mean that parents were less likely to exert pressure from their expectation standards on children who show high learning motivation.

Parents' emotional support in the learning situation was generally positively associated with children's achievement motivation in the previous findings, yet it alone might not be sufficient for enhancing achievement motivation (Pomerantz et al., 2012). Our findings correspondingly showed that a child who had higher perceptions of parents' emotional support than their siblings or sibling pairs who experienced higher emotional support from their parents than other unrelated children at age 11 did not have higher learning motivation 2 years later. Interestingly, DZ twins who had higher learning motivation than their siblings at age 11 showed higher perceptions of their parents' emotional support at age 13 even after controlling for individual children's characteristics, siblings' characteristics, and families' SES. This means that a parent's emotional support tends to be child-specific, and the individual child with a higher level of learning motivation tends to receive emotional support from their parent more than the other sibling. Given that strong relationships between children and their parents are positively related to students' motivational orientations and learning outcomes (Furrer & Skinner, 2003; Paulson, 1994; Peng & Wright, 1994; Pomerantz et al., 2012; Pomerantz, Wang, et al., 2005; Ryan & Powelson, 1991; Wang & Eccles, 2012), a child with lower motivation might need higher emotional support from their parents than their sibling with higher learning motivation.

The motivation literature has consistently highlighted the negative impact of parental control on children's achievement motivation (Grolnick & Pomerantz, 2009; Grolnick & Ryan, 1989), especially when children's autonomy, thoughts, feelings, and behavior in the learning environment are controlled by parents' commands, punishment, or coercive interactions (Barber, 1996; Baumrind, 1971; Grolnick & Pomerantz, 2009; Nelson & Crick, 2002). In our study, parental control was measured as students' experience of parents' demands, complaints, threats, and accusations that children lack concentration with regard to their poor school grades, which represented the typical controlling attitude of parents toward their children's low academic achievement. The current study did not find any association between children's perceptions of parental control and children's learning motivation. Although such parental behavior could have the intention to provide guidance to children, parental control is distinguished from parental structure and discipline (Grolnick & Pomerantz, 2009). Especially when parents use coercive parental behaviors, such as parental pressure, intrusiveness, domination, and assaults on children' individuality, parental control negatively affects student outcomes (Grolnick & Pomerantz, 2009) and did not affect individual children's or siblings' learning motivation in our study.

On the contrary, our findings highlight the importance of children's perceptions of their parents' learning encouragement, especially for children's learning motivation in school. Parents' learning encouragement consisted of items that refer to parental support for autonomous learning, including encouraging children to find the solution themselves, to ask a parent questions, or to ask questions in class for a deeper understanding. Such parental encouragement for children's autonomous learning (Boonk et al., 2018; Khan & Siraj, 2012; Martinez-pons, 1996) is assumed to help children perceive the importance of engaging in learning-related behavior (Joussemet et al., 2008), which further affects children's self-regulated learning motivation (Joussemet et al., 2008; Martinez-pons, 1996) and academic achievement (Boonk et al., 2018; Khan & Siraj, 2012). In our study, we presented empirical evidence of this murky new construct that has never been introduced in the literature before. Our findings on the reciprocal effect between parents' learning encouragement and children's learning motivation in school highlighted the role of parental support for children's autonomous learning motivation in the school context. Thus, the reciprocal interaction between each parent and each child in the home context has implications for individual children's successful learning in school.

Effects of Children's and Siblings' Characteristics

For effects of children's and siblings' characteristics, children's personality traits, school grades, and sex were related with the reciprocal associations between diverse dimensions of parental support and learning motivation. Differences in the siblings' personality traits of conscientiousness and openness differentiated their perceptions of their parents' emotional support 2 years later. This means

that when a parent provided learning support for siblings, the parent considered an individual child's personality. The siblings' average level of personality was also related to differences in parenting between one family and another. MZ and DZ twin pairs who had higher levels of conscientiousness than other unrelated children at age 11 had higher perceptions of their parents' emotional support and learning encouragement. Yet, DZ twin pairs who had a higher level of neuroticism than other unrelated children at age 11 had lower perceptions of parents' learning encouragement at age 13. Overall, children's higher levels of conscientiousness and openness were related to their higher perceptions of their parents' emotional support, whereas their higher levels of neuroticism were related to their lower perceptions of parents' emotional support in the learning context. On the other hand, children's higher levels of openness and conscientiousness were also related to their higher learning motivation. All these findings consistently highlight the effects of children's personality traits on the association between different degrees of parents' emotional support and their learning motivation within and between families.

As proposed in expectancy-value theory's model of family influences (Eccles, 2007), children's characteristics of achievement and biological sex along with parents' SES were also related to parents' supports. Interestingly, a child who achieved higher school grades than their sibling at age 11 had lower perceptions of their parents' learning encouragement but higher perceptions of parental control at the age of 13. This finding signaled the vicious cycle of increased parental control and decreased parental learning encouragement for the sibling with lower achievement. Female MZ and DZ twins tended to have higher perceptions of parents' learning encouragement and lower perceptions of parental control than male twins. Whether parental behavior differed on the basis of the children's gender or whether individual siblings' perceptions of their parents' learning encouragement and control differed by their gender, the substantial difference in parents' support between male and female children points to a possible gender stereotype in interactions between parents and children (Eccles, 2007). Given that gender plays a role in parents' and individual children's perceptions and educational choices in different academic fields (Eccles, 1994, 2011; Eccles, Wigfield, et al., 1993; Gaspard et al., 2015; Parker et al., 2012; Parsons et al., 1982), we suggest that more studies should investigate the effects of gender on the reciprocal associations between parents' domain-specific support and children's domain-specific learning motivation. Parent's SES was positively related to children's perceptions of parents' emotional support, which implies the macro-level influence of economic status on parenting behaviors (Bempechat & Shernoff, 2012; Davis-Kean, 2005). All these results bring insights into why parents' diverse supports differed between siblings and why it differed between families by highlighting the complex interplay between children's characteristics and parents' characteristics, which shape siblings' dynamic learning experiences in the family.

Limitations

Our study has several limitations. The major limitation is that the measurements of children's perceptions of parents' support and children's learning motivation were based on the children's self-reported answers only. Although parents' reports were not used in our study, it is children's reports that have more validity because what children think is more important than what their parents say they do. In addition, as our research centered on the children's individual perceptions of their parents' support, it was justified. Nevertheless, regarding the discrepancy between the children's perceptions of their parents' support and the parents' reports of their parenting practices (Korelitz & Garber, 2016), we would like to urge future studies to include parents' reports of their support for their children and conduct comparative analyses to determine whether the reciprocal effects can consistently be observed.

A variety of items were used to represent the diverse dimensions of parental support, which might explain the certain degree of incoherence with significant effects observed between the current findings and the results of prior studies (Fan et al., 2012; Gonzalez-DeHass et al., 2005). For instance, parents' expectations represented more of a parental expectation standard rather than parental aspirations in our study. Accordingly, the operationalization of the constructs in the current study were slightly different than in other studies. Yet, it is important to note that these problems are typical for motivation research in general. On the one hand, it actually increases generalizability across findings as it helps reveal which results generalize across the different operationalizations of the construct. Nevertheless, we would like to make a call that research in the field of motivation should try to establish a common set of measures to produce comparable findings across studies.

In addition, the children's perceptions of parental support and children's learning motivation were not domain-specific. Accordingly, our results represent interactions between parents and children in the general educational situation but did not show interactions within each academic domain. Given that parents' beliefs and children's learning motivation differ across diverse academic domains (Eccles et al., 1989; Parsons et al., 1982), we would like more studies to address the reciprocal associations in each academic domain.

Approximately 30% of the children did not participate in the second wave of data collection in comparison with the first wave of data collection, which may limit the generalizability of our findings. The main reasons for the lower participation rate in the second wave were nonresponse due to participants who objected to the transfer of their address when they moved and participants who withdrew their consent. For the school-aged students, the reasons we had missing data were the nonparticipation of the twins' parents (approximately 23.6%) and the twins' own personal refusal (only

0.5%). Nevertheless, for the twins who participated in both waves of data collection, there was not a high rate of missing responses. Wave nonresponse is quite a common problem in longitudinal studies in the field of developmental psychology (Jeličić et al., 2009), and we dealt with it by using a large number of covariates and FIML estimation (Graham, 2003).

Conclusions

Although the literature has generally viewed children as the recipients of parental support (Boonk et al., 2018; Jeynes, 2003, 2007), the present findings highlight that children's academic endeavors and interests in learning reciprocally contribute to their perceptions of their parents' learning encouragement. Such reciprocal effects differentiated siblings' learning motivation and their perceptions of their parents' learning encouragement across the 2 years. Yet, the differentiated educational development was only observed for siblings who resembled each other to a moderate degree, which implies effects of sibling resemblance on how parents treated the siblings. Given that the reciprocal effect was observed only for parents' learning encouragement but not for parents' expectations, emotional support, or control, the dimensions of parental support should be carefully considered by parents and researchers. In addition, children's personality traits, school grades, and biological sex were associated with reciprocal relationships between the children's perceptions of parental support and learning motivation, which is in line with expectancy-value theory's model of family influences (Eccles, 2007). All these findings consistently shed light on within-family motivational dynamics

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5. Study 3: What Happens With Comparison Processes When "the Other" is Very Similar? Academic Self-Concept Formation in Twins

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Author Note

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Abstract

According to the internal/external frame of reference (I/E) model (Marsh, 1986), individuals' academic self-concept is strongly influenced by comparing their achievement in one domain with their achievement in other domains and with the achievement of others. Research has typically found contrast effects such that high-achieving others have a negative effect on students' academic self-concept. Yet, what happens if the "other" is somebody very similar to oneself as in the case of monozygotic twins? We introduce the *mirror effect* to describe the effect of the co-twin's achievement on academic self-concept formation, which means that rather than serving as a contrast, the effect of the co-twin's achievement parallels the effect of a monozygotic twin's own achievement. We used data from two school-aged cohorts (11- and 17-year-olds) from a representative sample (N = 4,202) of monozygotic and dizygotic twins in Germany. We regressed twins' math and German self-concept on their own and their co-twins' math and German achievement. Internal and external comparison effects as postulated in the I/E model were replicated for both monozygotic and dizygotic twins across both age groups. In line with our hypothesis, the mirror effect was found in monozygotic twins only: Co-twins' achievement and twins' own achievement showed a parallel pattern of positive effects on academic self-concept within each domain and negative effects on academic self-concept between domains, duplicating the I/E pattern. Mirror effects tended to be more pronounced for older monozygotic twins. We argue that the mirror effect is likely caused by high interpersonal similarity.

Keywords: academic self-concept, social comparison, I/E model, mirror effect, twin, age-difference.

What Happens With Comparison Processes When "the Other" is Very Similar? Academic Self-Concept in Monozygotic Twins

Academic self-concepts are students' self-beliefs about their intellectual strengths and weaknesses (Byrne, 1984; Marsh et al., 1988; Marsh et al., 2017). Academic self-concepts have been shown to be associated with a number of important educational outcomes (see Marsh & Martin, 2011; Möller et al., 2009), including academic achievement (Huang, 2011), effort (Trautwein, Lüdtke, Roberts, et al., 2009), and career aspirations (Nagengast & Marsh, 2012). In line with Shavelson et al.'s (1976) seminal review article on the hierarchy and dimensional nature of academic self-concept, researchers have come to a consensus that academic self-concepts are domain-specific, with abundant research showing particularly strong associations between domain-specific self-concept and related outcomes (Marsh & Craven, 2006; Marsh et al., 2015; Marsh et al., 2005b; Möller et al., 2020; Parker et al., 2012). As such associations between academic self-concepts and outcomes such as achievement and career choices have been found longitudinally, academic self-concepts can be concluded to have a sustained impact on individuals' development in school and subsequent educational transitions (e.g., Gaspard et al., 2020; Parker et al., 2012).

Given the important role that academic self-concept plays in academic success, it is crucial to identify the mechanisms that underlie its formation. Internal and social comparison processes have been identified as important determinants of academic self-concept. Students use internal (or dimensional; Möller & Marsh, 2013; Möller et al., 2009) comparison processes in the development of self-concept in diverse academic domains, which lead to a contrast that increases academic self-concepts in students' comparably strong domains and to more negative academic self-concepts in students' weaker domains. In addition to this internal comparison process, Marsh (1986b) argued that a student's academic self-concept in a given domain is contrasted by social comparisons ("contrasts") with fellow students (a so-called external comparison process) in a downward direction (e.g., "I am better in math than the majority of my classmates"), thus resulting in the student's comparatively high academic self-concept in a specific domain. This complex pattern involving the effects of internal and external comparison processes on students' academic self-concepts is described in the internal/external frame of reference (I/E) model (Marsh, 1986b) and has received extensive empirical support (for a meta-analysis, see Möller et al., 2009; Möller et al., 2020).

However, it is important to ask whether internal and external frame of reference effects—basically two contrast effects—already tell the complete story of the comparison processes that underlie academic self-concept formation. In this article, we introduce the *mirror effect* hypothesis. The mirror

effect means that, rather than serving as a contrast, the effects of the achievement of a very similar other person parallel the effects of the first person's own achievement. For example, in the case of monozygotic twins, a co-twin's achievement and an individual monozygotic twin's achievement will show a parallel pattern of positive effects within a domain and negative effects between domains when the I/E model is applied (Marsh, 1986b). This mirror effect hypothesis is grounded in social comparison theory, which emphasizes the pivotal role of perceived similarity in the interpersonal association (Festinger, 1950, 1954; Goethals, 1986; Pettigrew, 1967), and it differentiates the socialization effect into either assimilation or competition (Abrams & Hogg, 2004; Hogg, 2000; Tajfel & Turner, 2010; Turner et al., 1979).

In the present study, we embrace the unique opportunity to test the mirror effect by using a large sample of 4,202 monozygotic (MZ) and dizygotic (DZ) twins, with the MZ twins constituting arguably the most similar "other" student one can imagine. Moreover, the fact that the data set comprised data from two school-aged cohorts (11- and 17-year-olds) allowed us to examine whether the strengths of the postulated mirror effect differed across age groups. Given that the stronger social and dimensional comparison effects have been reported for older rather than younger students (Möller et al., 2020), it is conceivable that mirror effects might be stronger in the group of secondary school students (Möller et al., 2020).

Internal and External Comparison Processes as Determinants of Academic Self-Concept

Academic self-concepts refer to people's beliefs about their abilities in given academic domains (Marsh et al., 1988; Shavelson et al., 1976). A substantial body of research has found support for a reciprocal relationship between academic self-concept and academic achievement (Marsh & Craven, 2006; Marsh & Martin, 2011; Seaton et al., 2014; Sewasew & Schroeders, 2019), and this is why developing a positive academic self-concept is held in high regard in education. In general, younger children tend to report fairly high academic self-concepts in most domains (Denissen et al., 2007; Eccles et al., 1993). However, as they pass through the grades from kindergarten to 12th grade, they develop a more balanced view of themselves, most likely fueled by experiences of success and failure in diverse domains (Harter, 1998, 2006; Muenks et al., 2018).

Students use multiple frames of reference, including internal, external, temporal, and criterion-based frames of reference, to compare and to evaluate their own ability within academic domains that are importance to them (Dijkstra et al., 2008; Möller et al., 2020; Skaalvik & Skaalvik, 2002). The I/E model developed by Marsh (1986b) combines two central comparison processes: the tendency of individual students to internally compare their academic achievement across domains (internal or dimensional comparison process; Möller & Marsh, 2013; Möller et al., 2009) and the tendency to externally compare

their own achievement level with that of surrounding comparison targets or a reference group (Dijkstra et al., 2008; Marsh et al., 2008).

With regards to external comparison processes, there is good evidence that students compare their achievement with the achievements of others in the educational context. When students engage in social comparisons with better achieving others, they tend to have lower academic self-concepts, whereas students' comparisons with lower achieving others contribute to increasing students' self-concepts regardless of the students' absolute levels of achievement (Marsh, 1987). Thus, when students have high achievement in a certain domain, they are likely to develop a high academic self-concept in the respective domain (Marsh, 1986a). More specifically, two equally able students will not have the same comparison targets available to them if they are in different environments: If there are many high-achieving students in a classroom, the likelihood of negative upward comparisons increases; conversely, if there are more low-achieving students in a classroom, students are more likely to look better than their fellow students in comparison (Marsh, 1987). Indeed, high-achieving fellow students in the same class and school have been shown to adversely affect individuals' academic self-concepts, a phenomenon known as the Big-Fish-Little-Pond-Effect (BFLPE; (Marsh et al., 2004; Seaton et al., 2013).

In addition to external comparisons with other students, an individual's achievement in a certain domain can negatively affect their academic self-concept in contrasting domains as a consequence of internal (or dimensional) comparison processes (Marsh, 1990b; Marsh et al., 2014; Möller & Marsh, 2013). For example, a person's math achievement negatively predicts the person's verbal self-concept when verbal achievement is statistically controlled for; likewise, verbal achievement negatively predicts math self-concept when math achievement is statistically controlled for (Marsh & Hau, 2004; Möller et al., 2020). In this article, we use the term *internal comparison processes* (rather than dimensional comparison processes) because of the central role of Marsh's (1986b) I/E model in our analyses.

In empirical studies on the I/E model, researchers typically use school grades (reported by teachers/schools or the students) and questionnaire data on students' self-concept. The predictions of the I/E model are then tested by using a set of regression analyses or structural equation modeling. As illustrated in the upper part of Figure 1, support for the I/E model is found when school grades positively predict academic self-concept in the corresponding domain (this is interpreted as support for external comparison processes) and negatively predict academic self-concept in the contrasting domain (support for internal comparison processes.)

The Mirror Effect: Twin Achievement as a Frame of Reference for Academic Self-Concept

There is very robust evidence for the I/E model (Möller et al., 2020), which basically emphasizes that contrast effects drive the formation of students' academic self-concept: Students contrast their achievement in a certain domain with the achievements of other students and contrast their own achievement across various domains. However, one might ask if there are situations in which such contrast effects are offset or even reversed. In the present article, we use the term *mirror effect* to describe such a pattern. We argue that such an effect might be found when students compare themselves with somebody who is very similar to themselves: Just like their image in a mirror, students use what they see in this other person as an additional information to form their image of themselves. In the present investigation, we focused on what are arguably the most similar dyads of students: twins (Hoffman, 1985; Plomin et al., 2001; Segal, 1984; Stewart, 2000).

There are good reasons to study the effects of close others on academic self-concept formation, given the breadths of potential comparison processes. According to Skaalvik and Skaalvik (2002), social comparisons with siblings or close friends may differ from social comparisons with classmates, for instance, because students may have more freedom to choose or not choose to use their friends or siblings as comparison targets, whereas classmates are forced upon students, leaving them no choice about comparison standards. At the same time, siblings are typically close and visible to each other, and social comparisons with family members are believed to be crucial for self-knowledge throughout early development (Alicke et al., 2009). Throughout childhood and adolescence, siblings learn from each other (i.e., social learning) but also sometimes attempt to differentiate (i.e., socially contrast) themselves from each other (Whiteman & Christiansen, 2008; Whiteman et al., 2007; Whiteman, McHale, et al., 2011) and compete with each other (Schachter et al., 1976; Tesser, 1980).

In the present article, we focused on twins, who are exemplary close others. Twins are often perceived and treated as a social unit, especially in childhood (Hoffman, 1985; Stewart, 2000). In their common family background and experiences, twins compare their similarities and differences in traits and qualities (Watzlawik, 2009). An important differentiation is between MZ and DZ twins due to their differential similarity and relationships. MZ and DZ twins have been empirically shown to perceive similarities with their co-twins to different degrees. For instance, MZ twins perceive fewer differences in their traits and other qualities than DZ twins do (Watzlawik, 2009). This finding is in line with studies that have found greater similarity in academic self-concept (Kovas et al., 2015), achievement (Gottschling et al., 2012), personality, and intelligence for MZ twins (McCartney et al., 1990), likely due to genetic influences rather than shared environmental influences, such as school and family (Gottschling et al., 2012;

Kovas et al., 2015). Compared with DZ twins, MZ twins are more likely to be dependent on (Penninkilampi-Kerola et al., 2005) and attached to their co-twins (Fraley & Tancredy, 2012; Tancredy & Fraley, 2006). Therefore, MZ twins tend to be less competitive and more cooperative with each other (Segal, 1984; Segal & Hershberger, 1999). Such qualitatively differential relationships exhibited by MZ and DZ twins suggest that social comparison processes in the formation of academic self-concept could differ by the status of being an MZ twin, as predicted in our mirror effect hypothesis.

The idea that "close others" might impact social comparison processes—as encapsulated in the mirror effect hypothesis—is not completely new. Back in the 1950s, social comparison theory postulated that interpersonal association is relative to the degree of perceived similarity (Festinger, 1950, 1954; Goethals, 1986; Pettigrew, 1967), and it differentiates the socialization effect into either assimilation or competition (Abrams & Hogg, 2004; Hogg, 2000; Tajfel & Turner, 2010; Turner et al., 1979). Specifically, assimilation to the successful comparison target was assumed to be amplified more when individuals compared themselves with someone to whom they felt very similar (Festinger, 1954). Individuals tend to cognitively classify themselves and their similar comparison targets as members of the same social category, namely, the in-group as opposed to the out-group (Turner et al., 1979). Thus, individuals are more likely to be influenced by the same referential information from in-group members and similar others than those in the out-group (Abrams et al., 1990; Turner et al., 1989). This assimilation effect among in-group members is enlarged according to the degree of mutually perceived similarity in the shared social context (Brewer, 1991). This enhanced identification with the in-group leads individuals to develop a social identity or social self-categories, based on which they regard the accomplishments and reputation of other in-group members as if those accomplishments were their own (Abrams et al., 1990; Brewer, 1991; Turner et al., 1994). Therefore, when in-group members are very similar to each other, they construct their self-concept on the basis of their perception of their individual attributes as well as their social-self shared with surrounding similar others (Turner et al., 1987).

A number of studies have found support for the existence of assimilation effects among close others. In social comparisons with close others, individuals who perceived themselves as competent in a certain domain were more likely to evaluate the strengths and weaknesses of close others directly rather than comparatively in their self-evaluations (Pelham & Wachsmuth, 1995). Similarly, in research on the self-esteem maintenance model (Tesser, 1980, 2004; Tesser & Schwartz, 2001), in tasks with low relevance to the self, individuals tended to enhance their self-concept as a consequence of a close other's (e.g., siblings) successful performance, presumably as a consequence of reflected glory processes (Tesser & Schwartz, 2001). In another study that is particularly relevant to the present article, MZ twins exhibited

a positive effect of upward comparisons with successfully performing co-twins on their general self-evaluations, whereas DZ twins and non-twins experienced a negative effect that resulted from upward comparisons with their siblings, suggesting that the very close relationship in MZ twin pairs buffered effects of negative comparisons on their general self-concept (Noller, 2005; Noller et al., 2008).

In recent decades, additional support for assimilation effects has been found in a number of studies (Mussweiler, 2001b; T. Mussweiler et al., 2004). However, this support was largely found in experimental settings in the lab in which similarity was experimentally manipulated (Mussweiler, 2001a), whereas a clear preponderance of contrast effects was documented in naturalistic learning settings (Marsh et al., 2007; Möller et al., 2009). In fact, in naturalistic learning settings, even when some support for assimilation effects was found, the contrast effects of comparing oneself with better achieving others were much stronger, especially in an actual learning context (Marsh, Seaton, et al., 2008; Trautwein, Lüdtke, Marsh, et al., 2009). For this reason, rather than adopting the term assimilation, we reserve the term mirror effect to describe the positive effect of making a comparison with the achievement of a very close other on one's own academic self-concept in a real-life setting.

Mirror Effects in Different Age Groups

From a developmental perspective, the I/E model has been studied across different age groups. Students increasingly differentiate between different self-concept domains as they enter secondary school (Marsh, Craven, & Debus, 1999; Shavelson et al., 1976). A recent meta-analysis showed stronger effects of both social and internal comparisons on academic self-concept for older than for younger students (Möller et al., 2020). Specifically, secondary school students showed stronger positive effects of achievement on the matching self-concepts and stronger negative effects of achievement on the nonmatching self-concepts in comparison with elementary school students (Möller et al., 2020). These results are in line with individual empirical studies that looked at age group as a moderator of the I/E model and social comparison (Lohbeck & Möller, 2017; Marsh, Abduljabbar, et al., 2015; Skaalvik & Valås, 2001; Weidinger et al., 2019). These findings highlight the importance of considering age differences to better understand the different comparison processes that drive the formation of academic self-concept.

These findings are in line with broader theoretical thinking. An empirical finding based on developmental theories suggested that the important developmental changes between early and late childhood differentiate students' use of social and dimensional comparisons for their academic self-concept (Weidinger et al., 2019). Very young students tend to have a very positive self-concept because it is less closely aligned with external indicators, such as their achievement, skills, and significant others' evaluations (Marsh, 1990a). However, as students gain more life experiences, older students get to learn

more about evaluative standards and their relative strengths and weaknesses in diverse domains (Wigfield & Karpathian, 1991). Therefore, older students' academic self-concept tends to be more aligned with their external academic achievements, and their self-concept becomes more differentiated (Marsh, 1990a). Social and dimensional comparisons are believed to play a major role in this development (Harter, 1988; Marsh, 1990a).

Given that the development of the identities of individual twins is closely related to their emotional and cognitive development (Amani & Shariatipour, 2021), one may further ask whether the ways in which twins construct their academic self-concepts differ by age. A meta-analysis of MZ and DZ twins showed declines in the resemblance between twins in intelligence, cognitive ability (verbal, quantitative, performance, perception, and IQ), and personality traits (activity, aggression, anxiety, dominance, emotionality, masculinity, sociability, and task orientation) with age (McCartney et al., 1990), indicating increases in each twin's individual experiences and environment for both MZ and DZ twins. In a comparison of MZ and DZ twins, DZ twins became less similar than MZ twins over time on cognitive ability (McCartney et al., 1990). Accordingly, DZ pairs were found to be more likely to individually make references to their own cognitive ability and to construct different achievement-related self-concepts within twin pairs, compared with MZ pairs (Richardson & Norgate, 2005). Interestingly, despite decreases in the resemblance between twins as they grow older, older MZ twins tend to feel more attached to their co-twin than younger MZ twins, whereas older DZ twins reported feeling less attached to their co-twin than younger DZ twins (Fraley & Tancredy, 2012). Thus, a comparative analysis of the construction of academic self-concept in different school-age groups of twins would offer valuable insights into what it means to grow up with a closely related, very similar other person and form individual academic self-concepts during the time spent in school.

Taken together, on the basis of the stronger social and dimensional comparison processes that more often exist in older than younger students (Möller et al., 2020), twins in their late school years are likely to observe their co-twin's achievement in order to construct their academic self-concept within and across domains more than younger twins in their early school years. Although both MZ and DZ twins are likely to experience a decrease in the resemblance of their academic achievement to their co-twin's achievement as they grow older (McCartney et al., 1990), older MZ twins are believed to show stronger mirror effects on their academic self-concept than younger twins on the basis of the previous findings of stronger attachments within twin pairs in older compared with younger MZ twins (Fraley & Tancredy, 2012). By contrast, both younger and older DZ twins are less likely to show mirror effects due to the

perceived contrasts between them, thus leading to sibling deidentification or non-reference (Whiteman, McHale, et al., 2011).

The Present Study

In the present study, we applied the mirror effect hypothesis to the effect of a co-twin's achievement on self-concept formation. More specifically, we used the well-supported observation that MZ twins typically have a very close relationship as a perfect opportunity to test the mirror effect hypothesis, which implies that, rather than serving as a contrast, the effect of a co-twin's achievement would parallel the effects of an individual MZ twin's own achievement on academic self-concept. More specifically, given that the similarity between MZ twins is high and almost perfect—like looking in the mirror—we hypothesized that we would find a mirror effect on academic self-concept when we added twins' achievement in different domains to the classical I/E model: As depicted in Figure 1, we hypothesized that an individual twin's achievement and the co-twin's achievement would show a parallel pattern of positive effects on their academic self-concept within domains and negative effects between domains, duplicating the I/E pattern. Importantly, the mirror effect of the co-twin's achievement on academic self-concept might differ between MZ and DZ twins because DZ twins tend to perceive each other as less similar and tend to have less close and more competitive relationships with their co-twins (Tancredy & Fraley, 2006). Thus, we expected the mirror effect to be especially strong for MZ twins. Regarding stronger social and dimensional comparison effects for older students (Möller et al., 2020), we expected stronger mirror effects among MZ twins in late secondary school than in early elementary school.

We used a large, representative sample of MZ and DZ twins in Germany stemming from the TwinLife study (Diewald, 2021; Hahn et al., 2016). Specifically, we used data from school-aged twins in two cohorts: 11-year-old and 17-year-old twins. Notably, only same-sex DZ twins were sampled in this study so that all twin pairs had the same sex.

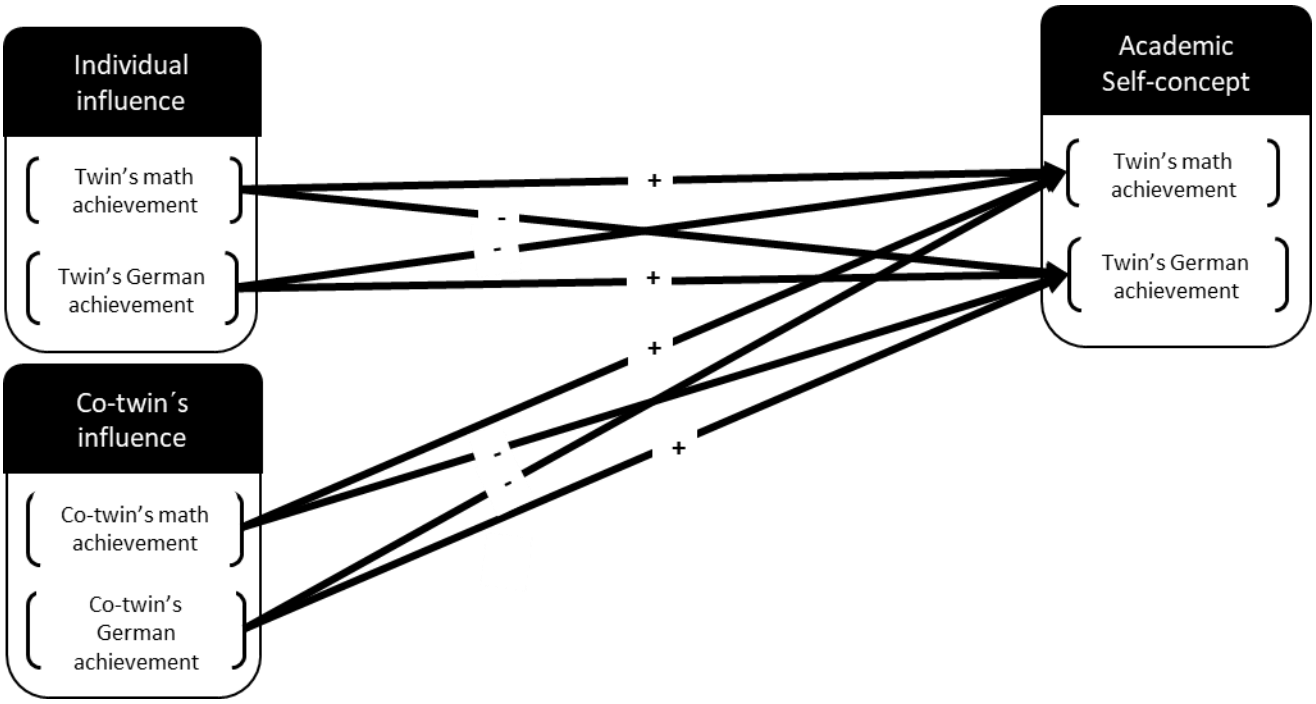
We addressed three research questions: First, we examined whether we could replicate the basic I/E model (Marsh, 1986b) using twin data. We focused on how a twin's own achievement in one domain influenced their academic self-concept in the corresponding and contrasting domains. Hence, in this analysis, we focused on only the upper part of Figure 1 and did not include the effects of co-twins' achievement. Generally, we anticipated that we would find support for the I/E model in both the MZ and the DZ twins. Although this first step of the analysis basically represented a replication of prior research with a somewhat specific sample (twins), it was important to make sure that the well-known I/E effects (see Möller et al., 2020) could also be found in this sample before we extended the analysis by also including the effects of the co-twins.

Second, we examined the mirror effect. To this end, we tested whether an individual twin's academic self-concept would also be affected by their co-twin's academic achievement. More specifically, we assumed that a twin would use their co-twin's achievement as a frame of reference for their own academic self-concept. On the basis of differences in perceived similarity and differential socialization across MZ and DZ twins (Fraley & Tancredy, 2012), we expected that the mirror effect would only be found in MZ twins. Statistically, as illustrated in Figure 1, we expected for MZ twins, but not for DZ twins, that an individual twin's achievement and their co-twin's achievement would show a parallel pattern of positive effects on their academic self-concept within domains and negative effects between domains, duplicating the I/E pattern.

Third, on the basis of findings that the strengths of I/E effects might differ across different age groups (Möller et al., 2020), we finally tested our full model separately for the two age groups (i.e., 11-year-olds and 17-year-olds) of MZ and DZ twins. With the comparison of two age groups, we aimed to address the important developmental changes that occur between early and late childhood regarding social and dimensional comparison (Weidinger et al., 2019). Specifically, although we expected to find mirror effects in both cohorts, we expected that these mirror effects would generally be stronger and more consistent in the older age group. Our expectation of stronger mirror effects for late secondary school students than early elementary school students is based on previous findings of a stronger attachment between twins in older than younger pairs (Fraley & Tancredy, 2012; Tancredy & Fraley, 2006) despite decreases in the twin pair's resemblance with respect to cognitive abilities and personality (McCartney et al., 1990).

Figure 1

The Hypothesized Twin Mirror Effect Model



Method

Data

The present study is based on data from the TwinLife study. The German Psychological Association confirmed (protocol numbers: RR 11.2009 and RR 09.2013) that the TwinLife study was in line with the ethical standards for research with human participants (P. 546; Mönkediek et al., 2019). Active consent was obtained during the field phase, and thank-you letters were sent to the interviewed participants after a successful interview (Hahn et al., 2016).

We reanalyzed data from the TwinLife longitudinal study, which is based on a representative sample of families with MZ and DZ twins in Germany (Diewald, 2021; Hahn et al., 2016; Lang & Kottwitz, 2020; Mönkediek et al., 2019). The data from this study are made available by the Leibniz-Institute for the Social Sciences (GESIS). Data collection began in 2014 with a population-based sample of 4,097 twin

families consisting of MZ and DZ twins, biological and or adoptive parents, stepparents (when applicable), and the twins' siblings and partners (Lang & Kottwitz, 2020). Twin families were drawn from local resident registers in communities with at least 5,000 inhabitants in Germany (Mönkediek et al., 2019). If two same-sex people with the same date of birth lived in the same household, the TwinLife researchers checked whether the selected persons were twins (Mönkediek et al., 2019). TwinLife used a probability-based sampling design that was designed to counteract the overrepresentation of MZ twins that has often been the case in other twin samples that have been based on self-recruitment (Lang & Kottwitz, 2020). To validate the representativeness of the sampling strategy, Twinlife compared the sample with a German household survey (i.e., the 2013 Microcensus) that is based on a nationally representative sample with regard to the twins' region of residence (i.e., east and west Germany), community size, German citizenship status, the highest educational and occupational status of the twins' parents, and the parents' monthly income. The distributions of the variables in the TwinLife sample were roughly comparable to the corresponding population values (Lang & Kottwitz, 2020).

Every other year, the survey was administered in participants' homes by applying face-to-face interviews (i.e., computer-assisted personal interviews), computer-assisted self-interviews, or paper-and-pencil interviews and/or by administering online questionnaires. In the other years, telephone interviews were used (Mönkediek et al., 2019). The survey participants who were over 10 years old were given a cash gift of 10 € after a successful interview. Sensitive topics were covered via computer-assisted self-interviews. School report cards were photographed as part of the computer-assisted interviews (Mönkediek et al., 2019).

The TwinLife longitudinal data included four cohorts, and we used only the data collected in the first wave in the year 2014. We only examined school-aged twins from the two birth cohorts consisting of individual twins who were 11 (N = 2,086) or 17 (N = 2,122) years of age. The other two cohorts were not examined in our study as they were not school-aged (around 5 and 23 years of age, respectively). Among the 4,208 twins in these two age groups, six individual twins did not have information about zygosity, and therefore, we did not include them in our study. After eliminating the twins with no information on zygosity, our sample consisted of 842 MZ twins (49.8% male) and 1,240 DZ twins (49.8% male) who were 11 years old and 996 MZ twins (43.8% male) and 1,124 DZ twins (41.8% male) who were 17 years old. As TwinLife only included data from same-sex DZ twins, our analysis was restricted to same-sex DZ twin pairs. According to the parental responses on individual school-aged twins, and after eliminating nonresponses due to unclear classification or no participation, 97% of the 1,884 individuals twins had grown up together

to the present day, 0.1% had lived separately to the present day, and 2.9% had sometimes lived separately to the present day.

Measures

Zygosity was determined by questionnaires administered to the parents of twins who were between 4 and 12 years of age (cohort 2) or by self-report questionnaires administered to twins who were older than 12(cohort 3) (Lenau et al., 2017). The questionnaires consisted of three sections that tapped into physical similarity, confusion from close resemblance (i.e., being confused for the other twin), and zygosity. To validate these questions, the results of an analysis of genetic material (i.e., the collection of DNA using buccal swaps) from a subsample of 328 twins was compared with either parent reports (*n* = 212) for twins between 4 and 11 years of age or self-reports (*n* = 116) for twins between 12 and 16 years of age. The classification of zygosity on the basis of the questionnaire was confirmed for 97% of the parent reports and 96% of the self-reports and was thus successfully cross-validated (Lenau et al., 2017). The rate of agreement between questionnaires and genotyping to determine zygosity was on a par with or better than in other twin studies (e.g., Goldsmith, 1991; Rietveld et al., 2000; Song et al., 2010).

Academic self-concept was assessed with three self-concept items in each domain of math and German adapted from a standardized German self-concept inventory (Dickhäuser et al., 2002). The students were asked to rate the extent to which each statement applied to them on a 5-point rating scale, with higher values indicating higher self-concept (Diewald, 2021; Hahn et al., 2016). The items were, "I am … in math/German? (1 = *not talented*, 5 = *very talented*)," "I know … in math/German? (1 = *a little*, 5 = *a lot*)," and "In math/German, many exercises are … (1 = *easy*, 5 = *difficult*; reverse coded)." The internal consistency of the scales ranged from α= .86 to α= .93 for math self-concept and from α= .81 to α= .87 for German self-concept across the older and younger cohorts and in the MZ and DZ twin groups. The rate of missing data ranged from approximately 0.7% to 18% for the math and German self-concept data for the MZ and DZ twins in each age group (Table 1).

Information about school grades was retrieved from photos that students had taken of their latest school report cards. Accordingly, school grades reflected achievement before academic self-concept had been assessed in the survey. However, these photos were missing for approximately 42% of 4,202 twins. When students did not submit the photo of their school grades, self-reported school grades were collected (Diewald, 2021; Hahn et al., 2016; Lang et al., 2020). We created a new school grade variable by combining the photographed school grades and self-reported school grades, which were substituted for the missing values. Hence, in total, we had information about grades for approximately 83.9% of 4,202 students. There were 10 students who submitted both photographed school grades and self-reported

grades, and all of them reported identical school grades, except for one student who reported higher self-reported grades than the photographed school grades. For this one student, we used the photographed school grades instead of the self-reported grades. Consequently, missing rate ranged from 14.5% to 18.2% for math grades and from 14.8% to 17% for German grades (for a detailed description, see Table 1). With regard to the validity of the self-reported grades, previous research showed a strong association between reported and actual grades for German students in different domains and grade levels (Dickhäuser & Plenter, 2005b). In Germany, school grades are assigned on the scale ranging from 1 (*very good*) to 6 (*insufficient*). For ease of interpretation, we recoded the school grades so that higher values indicated higher achievement. Descriptive statistics and proportions of missing data for academic self-concept and achievement in the different groups are reported in Table 1. More detailed information about missing data in photographed and self-reported school grades and the reasons for the missing data are reported in Table S1 in the Supplemental Materials.

Statistical Analyses

To address our first research question, we replicated the I/E model for the full sample of twins by regressing a twin's math and German self-concept on the twin's own math and German achievement within and across domains. We used the latent variable modeling approach for academic self-concept measures. In addition, we performed a multiple-group analysis using the two groups of twins (i.e., MZ vs. DZ). Specifically, we replicated the I/E model in each group and compared the difference between the MZ and DZ twins. In doing so, we used the likelihood ratio test of nested models using the scaled chi-square (Bryant & Satorra, 2012; Satorra & Bentler, 2010) to investigate the group differences in the regression analysis of the I/E model. In doing so, we compared the model fit of an unconstrained model with the fit of a model in which the regression paths were constrained to be the same across groups. In addition, we used the model constraint option in Mplus to test whether the regression coefficients of specific regression paths in the I/E model differed between the MZ and DZ twins.

In the next step, we extended this model to include the effects of the co-twins' achievement on the twins' academic self-concept (see Figure 1). To address the second research question, we additionally regressed math and German self-concept on the co-twins' math and German achievements to test effects on the twins' both matching and nonmatching self-concepts, controlling for the effects of their own achievement. We performed a multiple-group analysis in the two groups of twins (i.e., MZ and DZ). To investigate whether MZ and DZ twins differed in the regression model, we applied the likelihood ratio test of nested models using the scaled chi-square (Bryant & Satorra, 2012; Satorra & Bentler, 2010). In doing so, we compared the fit of a model with unconstrained regression paths from the co-twins' achievement

to the twins' academic self-concept with the fit of a model with the regression paths constrained to be the same across groups. In addition, we used the model constraint option in Mplus to test whether specific regression paths differed between the MZ and DZ pairs. Specifically, we tested for whether the regression coefficients for the paths from the co-twin's achievement to the twins' academic self-concept within and across domains were stronger for MZ than DZ twin pairs in order to test whether the mirror effect differed between the MZ and DZ twins.

To address our third research question, which referred to potential differences between the older and younger cohorts of students in the MZ and DZ twins, we performed a multiple-group analysis in four groups of 11-year-old MZ, 17-year-old MZ, 11-year-old DZ, and 17-year-old DZ twins in the regression analysis involving the I/E model that included the co-twin's achievement as an additional predictor. To test for age differences, we applied the scaled likelihood ratio test to the regression analysis for different age groups in each pair of MZ and DZ twins. In doing so, we compared the fit of the model with unconstrained regression paths representing the effect of the co-twin's achievement on the twins' academic self-concept with the fit of a model in which the regression paths were constrained to be the same across groups. We also examined whether the regression coefficient for the paths from the twins' and the co-twins' achievement to the twins' academic self-concept within and across the domains were stronger for the 17-year-old than for the 11-year-old twins in each MZ and DZ group.

To obtain standardized results for the regression paths in the structural equation model and their differences, we manually standardized the individual item indicators and fixed the first factor loading to 1 for all model constraint tests of MZ and DZ twins in each age group.

We used structural equation modeling in Mplus (Muthén & Muthén, 2017). We used the robust maximum likelihood estimator (MLR) and the design-based correction of standard errors and model fit statistics in Mplus (Muthén & Muthén, 2017) to account for the non-normality of the indicator variables and the nonindependence of observations that resulted from the nesting of twins within twin pairs. Accordingly, we defined a twin pair as a nesting/stratification variable in the models because our data included the same values in the data twice. To be specific, we controlled for the dependency of observations at the twin-pair level using a design-based data correction of standard errors and fit statistics (implemented with the Mplus command TYPE = COMPLEX (Stapleton et al., 2016).

Beyond the chi-square statistic, we evaluated the fit of our models by computing the following fit indices and using the following values as cutoffs for acceptable fit: comparative fit index (CFI) > .95, TLI > .95, RMSEA < .06, and SRMR < .08 (Hooper et al., 2008; Hu & Bentler, 1999).

As we studied cross-group comparisons between MZ and DZ twins as well as between the two age groups, measurement invariance tests were crucial to ensure that the items measured academic self-concept similarly between the groups (Vandenberg & Lance, 2000). Accordingly, we conducted a series of confirmatory factor analyses with two latent variables for math and German academic self-concept with increasing levels of invariance across the four groups of 11-year-old MZ, 11-year-old DZ, 17-year-old MZ, and 17-year-old DZ twins. On the basis of Meredith's (1993) suggestion to establish measurement invariance, we compared a sequence of increasingly more restrictive models: Model 1 hypothesized configural invariance by modeling identical loading patterns between groups but no restrictions on any parameters in the measurement model. Model 2 hypothesized weak measurement invariance by constraining the factor loadings to be equal across groups. Model 3 hypothesized strong measurement invariance by constraining the factor loadings and item intercepts to be invariant across groups. We found support for configural invariance, $\chi^2(32) = 159.895$, CFI = .985, TLI = .971, RMSEA = .065, SRMR = .028, weak measurement invariance, $\chi^2(44) = 184.395$, CFI = .983 , TLI = .977, RMSEA = .065, SRMR = .028, and strong measurement invariance, $\chi^2(56) = 192.035$, CFI = .984, TLI = .982, RMSEA = .050, SRMR = .032, as the decreases in model fit were in an acceptable range according to the criteria suggested by Cheung and Rensvold (2002) and Chen (2007). Accordingly, we applied strong measurement invariance across the four groups in the structural equation models to address our research questions.

Missing data (see Table 1 for the proportions of missing data) were handled with full information maximum likelihood estimation. This approach uses all available information and is based on the missing-at-random (MAR) assumption (Baraldi & Enders, 2010; Graham, 2009). To make the MAR assumption more plausible, we included parents' socioeconomic status, parental support, parental control, individual twins' personality (i.e., conscientiousness, neuroticism, openness), and sex as auxiliary variables in our analyses. To avoid bias, we carefully selected auxiliary variables that were either related to the school grades or related to the rate of missing data in school grade on the basis of the theoretical considerations (meta-analyses on academic achievements), correlation analysis ($r > .10$; van Buuren et al., 1999), or multivariate analysis with the predictors of missingness (Graham, 2003; Thoemmes & Rose, 2014).

Table 1

Descriptive Statistics and Correlation Matrix

	N	*M*	SD	Missing		1	2	3	4	5	6	7
11-year-old MZ				*N*	%							
1.Math grade	720	4.4	.91	122	15	1						
2.German grade	717	3.4	.94	125	15	.57	1					
3.Math grade: co-twin	-	-	-	-	-	.64	.48	1				
4.German grade: co-twin	-	-	-	-	-	.48	.70	.57	1			
5.Math self-concept	837	3.8	.82	6	0.7	.41	.10	.30	.12	1		
6.German self-concept	837	3.7	.84	6	0.7	.10	.36	.10	.30	.10	1	
7.Math self-concept: co-twin	-	-	-	-	-	.30	.12	.41	.10	.50	.10	1
8.German self-concept: co-twin	-	-	-	-	-	.10	.30	.10	.36	.10	.45	.10
11-year-old DZ												
1.Math grade	1046	4.5	.92	194	16	1						
2.German grade	1043	3.5	.96	197	16	.56	1					
3.Math grade: co-twin	-	-	-	-	-	.45	.31	1				
4.German grade: co-twin	-	-	-	-	-	.31	.47	.56	1			
5.Math self-concept	1232	3.8	.81	9	0.7	.49	.12	.19	.05	1		
6.German self-concept	1233	3.8	.86	11	0.9	.04	.32	.01	.14	.04	1	
7.Math self-concept: co-twin	-	-	-	-	-	.19	.05	.49	.12	.20	.05	1
8.German self-concept: co-twin	-	-	-	-	-	.01	.14	.04	.32	.05	.20	.04
17-year-old MZ												
1.Math grade	815	4.3	1.07	181	18	1						
2.German grade	827	3.3	1.02	169	17	.43	1					
3.Math grade: co-twin	-	-	-	-	-	.59	.36	1				
4.German grade: co-twin	-	-	-	-	-	.36	.57	.43	1			
5.Math self-concept	834	3.5	.99	162	16	.59	.06	.39	.05	1		
6.German self-concept	834	3.6	.91	162	16	-.07	.45	-.01	.36	-.25	1	
7.Math self-concept: co-twin	-	-	-	-	-	.39	.05	.59	.06	.48	-.16	1
8.German self-concept: co-twin	-	-	-	-	-	-.01	.36	-.07	.45	-.16	.54	-.25

(*Continue*)

Table 1. Continued.

	N	M	SD	Missing		1	2	3	4	5	6	7
				N	%							
17-year-old DZ												
1.Math grade	955	4.2	1.06	169	15	1						
2.German grade	952	3.3	1.04	172	15	.42	1					
3.Math grade: co-twin	-	-	-	-	-	.28	.21	1				
4.German grade: co-twin	-	-	-	-	-	.21	.40	.42	1			
5.Math self-concept	927	3.4	.99	197	18	.59	.05	.16	.00	1		
6.German self-concept	927	3.6	.89	198	18	-.04	.46	.03	.16	-.25	1	
7.Math self-concept: co-twin	-	-	-	-	-	.16	.00	.59	.05	.24	-.02	1
8.German self-concept: co-twin	-	-	-	-	-	.03	.16	-.04	.46	-.02	.20	-.25

Note. N= present numbers, M = mean, SD = standard deviation, MZ = monozygotic twins, DZ = dizygotic twins. Missing = missing data

Results

Descriptive Statistics and Preliminary Analyses

As a preliminary analysis, we investigated the correlations among all variables separately for the MZ and DZ twins and within the two age groups. Prior twin research has sometimes shown relatively high similarity in educational achievement and motivation in twin pairs (Plomin et al., 2001; Plomin et al., 1977). Such high similarity can make parameter estimates untrustworthy due to multicollinearity. However, as shown in Table 1, the correlations were not too high in any of the four subsamples and showed no signs of multicollinearity between variables as $r < .85$ according to the general threshold value (Bohrnstedt & Carter, 1971). The highest correlation in MZ twins was $r = .70$, and the highest correlation in DZ twins was $r = .56$. The correlations between the twins' and co-twins' school grades ranged from $r = .36$ to $r = .70$ for MZ twins and from $r = .21$ to $r = 47$ for DZ twins. As for the differential age groups, the correlations between the achievement measures were higher for younger twins than for older twins: They ranged from $r = .31$ to $r = .70$ for 11-year-old twins and from $r = .21$ to $r = .59$ for 17-year-old twins. As for the correlations within individual MZ and DZ twins and within different age groups, the correlations ranged from $r = .42$ to $r = .57$ for math and German achievement. As for the dependent variables, the correlations between the twins' and co-twins' academic self-concept ranged from $r = .10$ to $r = .54$ for MZ twins and from $r = -.02$ to $r = .24$ for DZ twins.

Focusing on the individual twins in each of the four groups, math and German self-concepts were weakly correlated for 11-year-old MZ twins ($r = .10$) and for 11-year-old DZ twins ($r = .04$). Math and German self-concepts were negatively correlated for 17-year-old MZ ($r = -.25$) and DZ twins ($r = -.25$). As is typically found in research on the I/E model (Möller et al., 2020), there were only weak correlations between the math and German academic self-concepts despite the rather substantial correlations in achievement, and the correlation between math and German academic self-concept was even negative in older students. The correlations were in line with the literature (Möller et al., 2009), thus providing additional evidence for the validity of our measures.

Replication of the I/E Model in the Twin Sample

With respect to the first research question, our findings showed that the I/E model (Marsh, 1986b) could be replicated in the full sample of twins (see the upper part of Table 2). Based on the criteria, the model fit criteria indicated a good fit in the full twin sample, $\chi^2(16) = 156.344$, $p < .001$, CFI = .993, TLI = .940, RMSEA = .033, SRMR = .010. With respect to the external comparison, the regression paths from the individual twins' math/German achievement to the corresponding academic self-concept were

positive and significant in the full sample of twins. For the internal or dimensional comparisons (Möller & Marsh, 2013), the paths from the individual twins' math/German achievement to the noncorresponding academic self-concept were negative and significant in the full sample of twins.

Table 2

Result of the Replication of the I/E Model for the Full Samples of Twins and for MZ and DZ Twins

	Math self-concept			German self-concept		
	β	SE	*p*	β	SE	*p*
Full Sample						
Math grade	0.62	0.02	< .001	-0.22	0.02	< .001
German grade	-0.22	0.02	< .001	0.48	0.02	< .001
MZ twins						
Math grade	0.61	0.03	< .001	-0.23	0.03	< .001
German grade	-0.23	0.03	< .001	0.50	0.03	< .001
DZ twins						
Math grade	0.62	0.02	< .001	-0.22	0.02	< .001
German grade	-0.21	0.02	< .001	0.47	0.02	< .001

Note. MZ = monozygotic twins, DZ = dizygotic twins. *p* = two-tailed *p*-value.

β = Standardized parameter estimates.

Next, we tested whether the model also held in the two groups of twins in our analysis (i.e., MZ and DZ). Our findings showed that the I/E model (Marsh, 1986b) could be consistently replicated for both the MZ and DZ twins (see Table 2). The fit indices indicated good fit for a multiple-group model of MZ and DZ twins with no further constraints beyond measurement invariance, χ^2 (40) = 204.617, $p < .001$, CFI = .992, TLI = .944, RMSEA = .032, SRMR = .013. For the external comparison, the regression paths from the individual twins' math/German achievement to the corresponding academic self-concept were positive and significant for all MZ and DZ twins. For the internal or dimensional comparisons (Möller & Marsh, 2013), the paths from the individual twins' math/German achievement to the noncorresponding academic self-concept were negative and significant for all MZ and DZ twins. To test whether there were differences in the regression patterns between the MZ and DZ twins, we compared the fit of an unconstrained model with the fit of a model with regression paths that were constrained to be the same across groups. The effects in the I/E model did not differ between the MZ and DZ twins, $\chi^2(4) = 2.29$, $p = .683$. No differences between the MZ and DZ twins in the four paths are reported in Table S2.

Testing the Mirror Effect

To test the mirror effects hypothesis, we added the co-twins' achievement as a predictor to the structural equation model, and we performed a multiple-group analysis in the two groups of twins (i.e., MZ and DZ). The fit indices indicated a good fit for a multiple-group model with no further constraints beyond measurement invariance, $\chi^2(56) = 230.464$, $p < .001$, CFI = .992, TLI = .951, RMSEA = .028, SRMR = .012. Adding the co-twins' achievement did not substantially alter the regression paths from the individual twins' achievement to their academic self-concept. Evidence for the mirror effect was only found in the sample of MZ twins: Independent of the individual twins' achievement effects, there were statistically significant effects of the co-twins' achievement on MZ twins' academic self-concept within as well as across domains. Specifically, independent of the individual twins' own achievements, the paths from the co-twins' achievement to MZ twins' matching self-concept were both positive and statistically significant (math: β = 0.12, SE = 0.03, $p < .001$; German: β = 0.16, SE = 0.03, $p < .001$). On the other hand, the paths from the co-twins' achievement self-concept in contrasting domains were both negative and statistically significant (math self-concept: β = -0.12, SE = 0.03, $p < .001$; German self-concept: β = -0.09, SE = 0.03, $p = .002$) for MZ twins. This indicated that the co-twins' achievement and the individual MZ twins' achievement showed a parallel pattern of positive effects on academic self-concept within each domain (i.e., math and German) and negative effects on academic self-concept between domains (see Table 3). In contrast to the MZ twin pairs, none of these coefficients from the co-twins' achievement in either math or German to academic self-concept in either domain were statistically significant for the DZ twins.

Table 3

Result of the Twin Mirror Effect in MZ and DZ Twins

	Math self-concept			German self-concept		
	β	SE	*p*	β	SE	*p*
MZ						
Math grade	0.56	0.03	< .001	-0.21	0.03	< .001
German grade	-0.18	0.03	< .001	0.42	0.03	< .001
Co-twin's math grade	0.12	0.03	< .001	-0.09	0.03	.002
Co-twin's German grade	-0.12	0.03	< .001	0.16	0.03	< .001
DZ						
Math grade	0.62	0.02	< .001	-0.22	0.02	< .001
German grade	-0.19	0.02	< .001	0.47	0.02	< .001
Co-twin's math grade	0.03	0.02	.251	-0.002	0.02	.946
Co-twin's German grade	0-.04	0.02	.109	-0.006	0.02	.796

Note. MZ = monozygotic twins, DZ = dizygotic twins. *p* = two-tailed *p*-value.

β = Standardized parameter estimates.

To test whether the mirror effect existed exclusively in MZ twins, we formally tested for whether the mirror effect differed between the MZ and DZ twins. The mirror effect differed for MZ- than DZ twins: The scaled chi-square test comparing a fully constrained model with a model in which we did not constrain the four regression paths that indicated mirror effects (i.e., effects of the co-twins' achievement) showed that these paths differed between the MZ and DZ twins, $\chi^2(4) = 22.09$, $p < .001$. When we explicitly compared the four coefficients between the MZ and DZ twins using model constraints (see Table S3), the requisite model constraints showed that the regression paths of the co-twins' achievement on the individual twins' academic self-concept differed between MZ and DZ twins within domains (math self-concept: β = 0.09, SE = 0.04, $p = .007$, German self-concept: β = 0.16, SE = 0.04, $p < .001$) and across domains (math self-concept: β = -0.08, SE = 0.04, $p = .027$, German self-concept: β = -0.09, SE = 0.04, $p = .017$). In line with our expectations, the effects of the co-twins' achievement on academic self-concept within and across the domains were stronger for MZ than DZ twins.

Age Differences in the Mirror Effect

With respect to the third research question about age differences in the groups of 11-year-old and 17-year-old twins, we performed a multiple-group analysis in the four groups of twins (i.e., 11-year-old MZ, 17-year-old MZ, 11-year-old DZ, and 17-year-old DZ twins) in the regression analysis of the I/E model with the co-twins' achievement as an additional predictor. The fit indices indicated a good fit for a multiple-group model with no further constraints beyond measurement invariance, $\chi^2(120) = 332.926$, $p < .001$, CFI = .990, TLI = .944, RMSEA = .030, SRMR = .015. Evidence for the mirror effect was found in the samples of different age groups in MZ twins (Table 4): For the 11-year-old MZ twins, a mirror effect on academic self-concept was found within a domain. Specifically, a path from the co-twins' math grade to math self-concept (β = 0.11, SE = 0.04, $p = .012$) was statistically significant, independent of the individual twins' achievement effects. This indicated that the co-twins' achievement and the individual twins' achievement showed a parallel pattern of positive effects on the twins' academic self-concept within a domain at the age of 11. For the 17-year-old MZ twins, a mirror effect on academic self-concept was found within as well as across domains. Specifically, independent of the individual twins' own achievements, the paths from the co-twins' achievement to 17-year-old MZ twins' matching self-concept were both positive and statistically significant (math: β = 0.12, SE = 0.03, $p < .001$, German: β = 0.20, SE = 0.04, $p < .001$). In addition, the paths from the co-twins' achievement to the twins' self-concept in contrasting domains were both negative and statistically significant (math self-concept: β = -0.15, SE = 0.04, $p < .001$; German self-concept: β = -0.09, SE = 0.04, $p = .010$) for 17-year-old MZ twins. This indicated that mirror effects were observed in both age groups in MZ twins, yet older MZ twins also showed mirror effects across domains.

In contrast to the MZ twin pairs, none of these coefficients from co-twins' achievement in either math or German to the twins' academic self-concept in either domain were statistically significant in either age group in DZ twins.

Table 4

Results for the Twin Mirror Effect in the Different Age Groups within MZ and DZ Twins

	Math self-concept			German self-concept		
	β	SE	*p*	β	SE	*p*
MZ						
11-year-olds						
Math grade	0.45	0.05	<.001	-0.14	0.05	.003
German grade	-0.17	0.05	.002	0.36	0.05	<.001
Co-twin's math grade	0.11	0.04	.012	-0.09	0.15	.062
Co-twin's German grade	-0.07	0.04	.092	-0.10	0.06	.086
17-year-olds						
Math grade	0.62	0.03	<.001	-0.25	0.03	<.001
German grade	-0.20	0.03	<.001	0.46	0.04	<.001
Co-twin's math grade	0.12	0.03	<.001	-0.09	0.04	.010
Co-twin's German grade	-0.15	0.04	<.001	0.20	0.04	<.001
DZ						
11-year-olds						
Math grade	0.54	0.04	<.001	-0.18	0.04	<.001
German grade	-0.17	0.03	<.001	0.41	0.04	<.001
Co-twin's math grade	0.01	0.03	.849	-0.03	0.04	.359
Co-twin's German grade	-0.04	0.03	.169	0.02	0.03	.614
17-year-olds						
Math grade	0.66	0.03	<.001	-0.25	0.03	<.001
German grade	-0.20	0.03	<.001	0.53	0.03	<.001
Co-twin's math grade	0.03	0.03	.283	0.01	0.03	.795
Co-twin's German grade	-0.04	0.03	.230	-0.02	0.03	.521

Note. MZ = monozygotic twins, DZ = dizygotic twins. *p* = two-tailed *p*-value.

β = Standardized parameter estimates.

To test for differences in the regression patterns between the 11-year-old and 17-year-old twins in each sample of MZ and DZ twins, we compared the fit of the unconstrained regression paths from the co-twins' achievement to the twins' academic self-concept with the fit of the model in which the regression paths were constrained to be the same across groups. The different age groups of MZ twins differed in the mirror effect: The scaled chi-square test showed that the 11-year-old and 17-year-old groups of MZ twins differed with respect to the effect of the co-twins' achievement in the regression analysis of the I/E model with the co-twins' achievement as an additional predictor, $\chi^2(4) = 12.31$, $p = .015$.

However, the requisite model constraint tests showed that the 11-year-old and 17-year-old MZ twins did not differ in any regression paths representing the effect of the co-twins' achievement on the twins' academic self-concept in math and German (see the upper part of Table S4). In other words: There was a (small) overall difference, but none of the differences in the single regression coefficients were large enough to be significant.

For the 11-year-old and 17-year-old DZ twins, the scaled chi-square test showed that they did not differ with respect to the regression analysis of the I/E model that included the co-twins' achievement as an additional predictor, $\chi^2_{OBJ}(4) = 3.87$, $p = .424$. The requisite model constraint tests also showed that the 11-year-old and 17-year-old DZ twins did not differ with respect to any regression paths the referred to the effects of the co-twins' achievement on the twins' academic self-concept (see the lower part of Table S4). Taken together, our tests showed that the mirror effect differed slightly for MZ twins from different age groups, but the difference between the different age groups was not found for DZ twins.

Discussion

In this article, we introduced the mirror effect hypothesis, which proposes that, rather than serving as a contrast, the effect of the achievement of a co-twin from an MZ twin pair parallels the effect of the twin's own achievement. We used a large sample of MZ and DZ twins to test the mirror effect by adding it/incorporating it into to the well-known I/E model (Marsh, 1986), which holds that a student's domain-specific self-concept is strongly influenced by contrasts between various domains within the student as well as contrasts with the achievement of others (Marsh, 1986b; Marsh et al., 2008; Möller et al., 2009). Research has typically found negative effects on academic self-concept when individual students perceive a "contrast" with high-achieving others in the learning context (Marsh, Seaton, et al., 2008). In view of the mirror-like similarity in MZ twin pairs, however, we hypothesized a mirror effect of a co-twin's achievement on MZ twin's academic self-concept (see Figure 1). In line with our expectations, the present finding showed that the co-twins' effect duplicated the individual MZ twins' own achievement effect on the twins' academic self-concept, as if looking in the mirror. The co-twins' achievement and the individual MZ twins' achievement showed a parallel pattern of a positive effect on the twins' academic self-concept within domains and a negative effect across domains when they were considered together in an extended I/E model. Conversely, no such effects were found for DZ twins. This finding suggests that even "high similarity" is not enough for the mirror effect to occur but only if there is "perfect similarity" between the comparison targets. Lastly, within the MZ groups, the pattern varied between age groups. The mirror effect was shown in both age groups for MZ twins, but the effects tended to be more pronounced in the older students and were consistently found within and across domains.

The Mirror Effect: Duplicating Internal and External Comparison Effects in MZ Twins

Our analysis began by replicating the well-known I/E model (Marsh, 1986b) effects that have been reported many times (Möller et al., 2020). Our results are consistent with the assumption that academic self-concept in MZ and DZ twins is associated with their achievement in both math and German, with positive predictive effects of achievement in the corresponding domain and negative predictive effects of achievement in the noncorresponding domain on academic self-concept, which is in line with the theoretical assumptions of the I/E model (Marsh, 1986b). The regression weights of these effects were statistically the same between MZ and DZ twins. The successful replication of the I/E model in our twin sample substantiated the idea that twins use multiple frames of reference to make internal comparisons of their own achievement across domains and external comparisons with others (e.g., their classmates) to evaluate their own achievements for their academic self-concept. This means that the current findings of twins are in line with and comparable to the general findings based on I/E model.

The robust evidence for the I/E model (Möller et al., 2020) in our sample confirmed that the perceived contrast with high-achieving others typically has a negative effect on a student's academic self-concept as implied in the observed positive effect of individual twins' own achievement on their academic self-concept within domains. However, we postulated that such a contrast effect might be offset or even reversed if a student compared themself with an "other" who was perceived to be very similar, as in the case of MZ twins. More precisely, we postulated that the effect of the achievement of co-twins would parallel the effects of twins' own achievement on academic self-concept—an effect that we labeled the mirror effect. In the present investigation, mirror effects were indeed found for MZ twins but not for DZ twins. More specifically, the effect of co-twins' achievement on MZ twins' academic self-concept duplicated the pattern of the I/E model with respect to effects of individuals' achievement on their own academic self-concept, with positive comparison effects within domains and negative comparison effects across domains (Marsh, 1990b; Möller et al., 2020). It is important to note that these effects of co-twins' achievement were found while controlling for twins' own achievement such that the mirror effects cannot be explained by the high correlation between the two twins' achievements. Rather, the MZ twins used their co-twins' achievement as a frame of reference for their own academic self-concept. Such mirror effects were observed for younger MZ twins for the comparison within an academic domain and for older MZ twins within and between domains. Hence, just like their image in a mirror, MZ students looked at very similar co-twins' achievement to define themselves, offsetting typical contrast effects.

The Mirror Effect: Duplication, not Assimilation

The finding that the mirror effect was only found for MZ but not for DZ twins is of high theoretical importance in a long-standing debate about so-called assimilation effects in the development of self-concept. Going back to Festinger (1954), research on social comparison has highlighted potential assimilation effects that are believed to be amplified when the target and receiver are similar. Such assimilation effects have been confirmed in highly controlled lab experiments (e.g., Mussweiler, 2001a), whereas there has been less conclusive evidence for them in natural learning environments, if they were found at all (see Trautwein, Lüdtke, Marsh, et al., 2009). Our finding indicates that the assumed "assimilation" takes place only when students look at the achievement of a perfectly similar comparison target. On the basis of this exceptionally close similarity, we refer to the observed pattern of results as a mirror effect to differentiate it from an assimilation effect because—by all standards of similarity established in prior lab research on assimilation—assimilation should have taken place in DZ twins as well. The current finding of academic social comparisons in twins may be seen as an impressive corroboration of previous theories and findings of MZ twins' very special relationship with their co-twin (Fraley & Tancredy, 2012; Tancredy & Fraley, 2006).

The absence of mirror effects in DZ twins is also very interesting. Although DZ twins are often very close to each other, their closeness or similarity was apparently not strong enough to lead to mirror effects. Indeed, some levels of competitiveness are often found in DZ twin relationships (see Segal & Knafo-Noam, 2018; Segal & Hershberger, 1999), and this competitiveness may have counteracted any mirror effects. As with the MZ twin effects, the DZ twin effects are of high theoretical interest as they can inform research on so-called local dominance effects in self-concept development. In general, research on social comparison effects has found that the achievement of the most proximal learning environment (e.g., the course or class rather than the school or a specific type of school in tracked school systems) provide the most important frame of reference for social comparisons (Marsh et al., 2014; Zell & Alicke, 2009). However, in a recent study (Koivuhovi et al., 2020), the immediate peer group within a classroom seemed to have a less important effect on academic self-concept than the overall class-average achievement, although contrast effects were found for both peer group achievement and class achievement when they were investigated separately. Unfortunately, there were no nontwin peers in our sample, so we cannot add any such comparisons to our results. Therefore, one can only speculate about whether the lack of support for any mirror effects in DZ twins signals an additional lack of support for local dominance effects. Alternatively, contrast and assimilation effects may have simply cancelled each other out in this group of students.

Relatedly, in our study, we examined “real” twins. Of course, the question arises as to whether there could be mirror effects as well in “virtual” or “emotional” twins in real-world educational settings (i.e., dyads of students who are highly attached to each other despite a lack of family relationship, rendering them essentially more strongly attached than DZ twins). This is an intriguing question, but it is one that obviously cannot be answered on the basis of the current sample. In fact, large samples of students would have to be obtained along with detailed information about their emotional bonds to test such effects.

Mirror Effect: Developmental with Age

From a developmental perspective, the comparison processes would be important in later school years when students have the cognitive capacities needed to consider all of the social and dimensional comparisons together. It might also be more important for them to find out about their individual strengths and weaknesses as they have to find a suitable career path (Harter, 2003; Marsh, 1990a; Wigfield & Karpathian, 1991). Given that internal and external comparison effects are generally stronger for older rather than younger students (Marsh, Abduljabbar, et al., 2015; Möller et al., 2020), we had expected that the mirror effect would be stronger for 17-year-old than for 11-year-old twins. In fact, some mirror effects were found in both age groups in MZ twins, but the effects tended to be more pronounced and consistent for older twins. The effect was found both within and across domains for older twins, whereas younger twins showed the effect only within a domain.

Although the different age groups of MZ twins did not differ in the single regression paths from co-twin’s math and German achievements to individual twin’s academic self-concepts within and across the domains, there was a (small) overall difference between the 11-year-old and 17-year-old twins according to the chi-square test. In general, there was tentative evidence supporting the proposed developmental process, but the differences were not expressed as strongly as we had expected. Nevertheless, the finding is interesting as the 17-year-old MZ twins showed the slightly stronger or at least consistent mirror effects on their academic self-concept within and across domains despite the larger difference between their achievements and their co-twin’s achievements than 11-year-old MZ twins did (i.e., correlations). This could mean the mirror effects in 17-year-old MZ twin pairs buffered the possible contrast effects of comparing their increasingly different achievements throughout the school years. Given that twins’ differentiated individual identity develops more actively in late adolescence (Amani & Shariatipour, 2021), 17-year-old MZ twins’ manifestation of the consistent and slightly stronger mirror effects on their academic self-concept compared with 11-year-old MZ twins is noteworthy from a developmental perspective. The finding of a (small) overall stronger mirror effect found for older twins is

in line with and may contribute to the additional evidence of the increased attachments within MZ twin pairs for older compared with younger twin groups (Fraley & Tancredy, 2012)This may be the case even though older twins tend to be less similar in cognitive ability, personality traits, and temperament and tend to show increases in their individual experiences throughout their development (McCartney et al., 1990). All of these findings may suggest that the mirror effect develops only moderately with age—in line with what has been documented for internal and external comparison effects (Möller et al., 2020) and the stronger attachment between twins for older versus younger twin pairs (Fraley & Tancredy, 2012; Tancredy & Fraley, 2006).

Limitations

The present study found support for the mirror effect in a nationally representative sample of MZ and DZ twins that was uniquely well-suited to test this effect. Nevertheless, as in all studies, there are some limitations that should be noted. First, although the present study drew on social comparisons within twin pairs, we did not directly measure social comparison processes between twins. Rather, we measured them only indirectly by assessing the effect of the co-twins' achievement on academic self-concept. This is the standard procedure in research on social comparison effects in real-world learning environments, and given the large samples needed for this kind of research, practical issues do not typically allow researchers to study social comparison processes in the learning situation. Nevertheless, researchers should use any opportunities they can find to focus more on processes.

Second, we used school grades as a proxy for achievement, rather than standardized achievement tests. Grades are sometimes criticized for their assumed lack of validity (e.g., Mattern et al., 2011), However, using grades is the standard procedure in research on the I/E model for good reasons: Grades are very important for placement decisions, and they are more visible and salient to students. Not surprisingly, more pronounced patterns in line with the I/E model tend to be found for grades than for tests (Möller et al., 2009).

Third, despite the high overall quality of the data we used in our analyses, there were missing data on some variables, specifically for the photographed school grades. To deal with missing data on school grades, we substituted self-reported grades for missing data on the photographed school grades, but this might raise concerns with regard to self-report biases (Cole & Gonyea, 2010) that, of course, we cannot fully rule out. However, prior research on German students showed a very strong and almost perfect association between reported and actual grades (Dickhäuser & Plenter, 2005b; Sticca et al., 2017) in a similar setting (a research study with no personal stakes for the participants), indicating that self-reported grades most likely do not pose a great threat to validity in our study. Furthermore, in our analyses,

we dealt with missing data by including a set of auxiliary variables to make the MAR assumption for missing data as plausible as possible (Graham, 2003; Thoemmes & Rose, 2014).

Conclusions

Drawing on a large sample of twins, we introduced the mirror effect and thereby made a pivotal contribution to the academic self-concept research field. The mirror effect was found exclusively in MZ twins: The co-twins' achievement had an impact on twins' academic self-concept, resembling the I/E pattern of individual twins' comparisons of their own achievement within and across domains. The difference between MZ and DZ twins further highlights the substantial difference between perfectly and highly similar comparison targets. Furthermore, the mirror effect tended to be more pronounced for older MZ twins, thus providing further evidence that comparison processes become more important toward the end of students' school years. We look forward to further tests of this effect in additional data sets and across different settings in the future.

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Table S1.

Description of valid and missing data of school grade.

	Math grade Photographed		German grade Photographed		Math grade self-report		German grade self-report	
	N	Percent	N	Percent	N	Percent	N	Percent
Valid	2438	57.9	2445	58.1	1113	26.4	1109	26.4
Missing	1770	42.1	1763	41.9	3905	73.6	3099	73.6
-96					89	2.1	93	2.2
-95					2988	71.0	2988	71.0
-94	234	5.6	234	5.6				
-92	1355	32.2	1355	32.2	18	.4	18	.4
-89	106	2.5	103	2.4				
-88	46	1.1	40	1.0				
-86	29	.7	31	.7				

Note. -96= I can't remember, -95= doesn't apply, -94 = technical error (i.e., faulty insertion), -92 = no participation in survey mode, -89 = unreadable, -88 = subject legible but grade illegible, -86 = not available/empty/not codable.

Table S2.

Regression Path Difference in between MZ- and DZ Twins in Classical I/E Model.

	Path differences		
Regression path	β	*SE*	*p*
MZ vs. DZ			
Math grade – math self-concept	-0.01	0.04	.749
German grade – math self-concept	-0.03	0.03	.461
Math grade – German self-concept	-0.01	0.03	.669
German grade – German self-concept	0.04	0.03	.286

Note. MZ = monozygotic twins, DZ = dizygotic twins. *p* = Two-tailed p-value.
β= Standardized parameter estimates.

Table. S3

Regression Path Difference in between MZ- and DZ Twins in Mirror Effect Model.

	Path differences		
Regression path	β	*SE*	*p*
MZ vs. DZ			
Math grade – math self-concept	-0.06	0.04	.108
German grade – math self-concept	0.007	0.04	.843
Co-twin's math grade – math self-concept	0.09	0.04	.007
Co-twin's German grade – math self-concept	-0.08	0.04	.027
Math grade – German self-concept	0.01	0.04	.759
German grade – German self-concept	-0.05	0.04	.191
Co twin's math grade – German self-concept	-0.09	0.04	.017
Co-twin's German grade – German self-concept	0.16	0.04	<.001

Note. MZ = monozygotic twins, DZ = dizygotic twins. *p* = Two-tailed p-value.
β= Standardized parameter estimates.

Table. S4

Regression Path Difference in between Twins of Different Ages in Mirror Effect Model.

	Path differences		
Regression path	β	*SE*	*p*
MZ (17- vs. 11 years)			
Math grade – math self-concept	0.17	0.06	.002
German grade – math self-concept	-0.03	0.06	.586
Co-twin's math grade – math self-concept	0.02	0.05	.754
Co-twin's German grade – math self-concept	-0.07	0.06	.175
Math grade – German self-concept	-0.11	0.06	.044
German grade – German self-concept	0.09	0.06	.140
Co twin's math grade – German self-concept	-0.01	0.06	.926
Co-twin's German grade – German self-concept	0.10	0.07	.128
DZ (17- vs. 11 years)			
Math grade – math self-concept	0.12	0.05	.011
German grade – math self-concept	-0.03	0.04	.526
Co-twin's math grade – math self-concept	0.03	0.05	.546
Co-twin's German grade – math self-concept	0.001	0.05	.985
Math grade – German self-concept	-0.06	0.05	.169
German grade – German self-concept	0.13	0.05	.005
Co twin's math grade – German self-concept	0.04	0.05	.385
Co-twin's German grade – German self-concept	-0.04	0.05	.418

Note. MZ = monozygotic twins, DZ = dizygotic twins. *p* = Two-tailed p-value.
β= Standardized parameter estimates.

6. General Discussion

The empirical findings from the three studies provided insights into how an individual child's and their sibling's characteristics affect the educational dynamics within the family. Drawing from expectancy-value theory's model of family influences on children's motivation and achievement (Eccles, 2007; Eccles, Arberton, et al., 1993), the dissertation had four hypotheses.

With respect to the first hypothesis on children's different experiences with their parents within the family, the first study showed empirical evidence of parents' child-specific beliefs about their children's academic ability. Each mother and father differed in their perceptions of each child's ability in math and German as shown in the variance in each parent's response to their beliefs about each child's academic ability. At the same time, the parents also had general perceptions of the siblings' abilities in math and German. For the children's experiences of parental support, the second study showed that parents' emotional support and learning encouragement were child-specific and were influenced by each sibling's relative learning motivation. Parents' general support for the siblings' learning tended to be influenced by the siblings' general personality traits.

With regard to the second hypothesis on the children's effects on their educational outcomes, the third study showed that an individual twin's achievement along with their co-twin's achievement had a positive effect on each twin's academic self-concept within each domain and a negative effect on their academic self-concept between domains, duplicating the patterns from the I/E model (Marsh, 1986b). This means that an individual child's achievement and their sibling's achievement had a similar pattern of effects on the individual child's academic self-concept within and across domains. As the effects were exclusively found in MZ twins who are perfectly similar comparison targets for each other, we theorized that this was a mirror effect. Mirror effects tended to be more pronounced for older MZ twins.

With regard to the third hypothesis on children's effects on parents, the first study showed tentative evidence that parents use each child's own achievement and their sibling's achievement as frames of reference for their beliefs about the child's academic abilities within and across domains. Yet, a lack of a clean pattern of results called for a cautious interpretation of our results. In the third study, we found reciprocal relationships between perceived parental learning encouragement and children's learning motivation from age 11 to age 13. The reciprocal relationship differed between siblings but only for DZ twins. Yet we did not find such an effect for parents' expectations, parents' emotional support, or parental control. In addition, children's personality traits, school grades, and sex were related to parents' emotional support, parents' learning encouragement, as well as children's learning motivation.

With regard to the fourth hypothesis on effects of sibling resemblance, the effects of co-twins' achievement on academic self-concept within and across domains were stronger for MZ than for DZ

twins in the third study. The reciprocal effect between children's learning motivation and their perceptions of parental learning encouragement was substantially larger for DZ than for MZ twins.

Overall, the empirical findings from the three studies showed a substantial influence of an individual child's and their sibling's characteristics on academic self-concept and parents' beliefs and support and accordingly contribute to a new perspective on the model of family influences proposed by Eccles and colleagues (Eccles, 2007; Eccles et al., 1983). In the following, I discuss our findings in more depth and outline potential avenues for future research. The last two sections of the Discussion address theoretical and methodological implications as well as the limitations of the dissertation and a conclusion.

6.1. Sibling Dynamics in Academic Socialization Within the Family

6.1.1. Parents' Child-Specific Beliefs and Support

Studies on parental influence have primarily focused on the general childrearing climate in the home environment and have typically addressed how parents' general behaviors and beliefs affect children's achievement motivation (Wigfield, 1994; Wigfield & Eccles, 1992). Previous reviews of the relevant literature have correspondingly highlighted that parents' provision of appropriate levels of structure, consistent and supportive parenting, and observational learning for children's overall orientation promote achievement (Wigfield et al., 2015). In view of parents' influences at the family level, attention has focused on how family demographic characteristics, such as SES, ethnicity, culture, and immigration status shape parents' beliefs and behaviors in different families (Kim et al., 2020; Song & Hattie, 1984; Yamamoto & Sonnenschein, 2016). Although much has been learned about parents' general beliefs and support in the home across different families, we still know only a little about how parents' beliefs and support vary across individual siblings within a family.

The current dissertation addressed this research gap by focusing on the level of the individual child as well as the sibling level when exploring the influence of children's characteristics on parents' beliefs and support within the family context as proposed by the model of family influences (Eccles, 2007; Eccles, Arberton, et al., 1993). Yet, the current dissertation additionally considered different socialization agents in the family, such as the mother, the father, and each sibling and assumed influences at the levels of the family, parents, siblings, and each specific child on parents' beliefs and support within the family. Empirical findings from the first study showed that parents' beliefs about children's academic ability varied at the family level, the parent level, the sibling level, and the level of each specific child. The substantial variance in parents' beliefs found at each level indicated the extent to which parents' beliefs about children's academic abilities differed between siblings and between parents but also the extent to which parents had general beliefs about siblings' academic abilities. This

finding brought new insights into different family members' individual-level and group-level influences on parents' beliefs within the family as claimed by family systems theories (Parke & Buriel, 2007). In this regard, the findings from the first study offered insights into how and why parents develop similar and different beliefs about siblings' academic abilities.

An equally important finding is that parents tended to have more child-specific beliefs about each sibling than general beliefs about both siblings. In other words, parents' beliefs about a child's academic ability differed substantially between siblings. Accordingly, this finding shifted our focus from general parental beliefs about children toward diversified parental beliefs about each sibling's academic ability. The empirical finding of substantial variance in parents' beliefs observed at the level of each individual child and the sibling level initiates an interesting discussion about how diverse parents' beliefs are about children's academic abilities across siblings. On the one hand, the finding may imply the substantial influence of siblings' different levels of achievement on parents' perceptions and evaluations of each sibling's academic ability. In previous findings, initial variation in individual siblings' achievement levels predicted parents' future educational expectations of each child above and beyond the parents' previous educational expectations (Briley et al., 2014). In this regard, an individual child's achievement would have shaped a parent's child-specific beliefs. On the other hand, individual siblings' other characteristics could have diversified parents' beliefs about a child's academic ability independent of siblings' different achievement levels. For instance, sibling's birth order and sex were identified as factors that influenced parents' beliefs in prior studies, such that parents tended to have higher expectations for older than for younger children (Ernst & Angst, 1983) and higher ability beliefs for sons than daughters, especially in STEM subjects (Šimunović & Babarović, 2020). If this is the case, parents' gender stereotypes and other potential biases regarding sibling status should be investigated further. Taking all things into consideration, the first study's findings indicate that parents compare siblings' individual characteristics to construct their beliefs about each child's academic ability. Thus, in psychological research on parents' beliefs, there is a need for more studies in which individual children's and their siblings' characteristics are taken into account, as claimed in the model of family influences by Eccles and colleagues (Eccles, Arberton, et al., 1993).

Given that parents' beliefs are expected to have an impact on parents' behavior (Eccles, 2007; Wigfield et al., 2015), parents' general and child-specific beliefs shown in the first study further point to siblings' shared and individual experiences with parental support, respectively. In the second study, the two siblings had shared perceptions of their parents' expectations and encouragement at age 13 influenced by their overall level of learning motivation at age 11, controlling for the child's and sibling's characteristics of sex, school grades, personality traits, family SES, and learning motivation. In parallel, each sibling also had individual perceptions of parents' emotional support and parents' learning encouragement. Specifically, the second study showed that an individual child with a higher level of

learning motivation tended to receive more emotional support and learning encouragement from parents than their sibling, controlling for the child's and sibling's characteristics. The empirical finding of siblings' shared perceptions of parents' general support and their individual perceptions of parents' learning support guided our attention to the sibling and individual levels of parental influences within a family.

On the basis of the empirical findings of parents' child-specific beliefs and support in the first and second studies, one may further ask about their effects on siblings' educational development. For this, parents' child-specific learning encouragement had an impact on individual children's learning motivation, whereas parental encouragement for both siblings did not have an impact on the children's learning motivation as shown in the second study. The findings are in line with the previous empirical findings that individual child-specific social influence in the family is the most important influence for children's academic motivation and is more important than siblings' shared experiences (Daniels & Plomin, 1985; Dunn & Plomin, 1990; Turkheimer & Waldron, 2000). The current finding also corresponds to the hypothesis from expectancy-value theory's model of family influences (Eccles, 2007; Eccles et al., 1983), which highlighted the importance of parents' child-specific beliefs and support for children's educational outcomes. In this regard, we would like to see more studies investigate the effects of parents' child-specific beliefs and support on children's educational outcomes.

6.1.2. Effects of Children's Characteristic on Their Educational Development

Drawing from the model of family influences by Eccles and colleagues (Eccles, 2007; Eccles, Arberton, et al., 1993), in the current dissertation, I hypothesized that an individual child's and their sibling's prior achievement would be important predictors of academic self-concept. To address these hypotheses, we investigated how an individual child's prior achievement affected their own academic self-concept as well as their sibling's academic self-concept. Accordingly, when applying the I/E model to school-aged twins, an individual child's academic achievement was identified as a powerful antecedent of their academic self-concept in line with prior studies (Möller et al., 2020). Consistent with the theoretical assumptions of the I/E model (Marsh, 1986b) and the robust prior findings that were based on the I/E model (Möller et al., 2020), MZ and DZ twins constructed their academic self-concepts by externally comparing their academic achievement with other students in the school and also by internally comparing their achievement in the math domain with their own achievement in the German domain.

But what is more intriguing is that co-twin's achievement served as an additional frame of reference for an individual MZ twin's academic self-concept. The co-twin's achievement had a positive impact on an individual MZ twin's academic self-concept within and across academic domains, replicating the patterns of the I/E model (Marsh, 1986b). This means that the effect of a co-twin's

achievement showed a pattern that was similar to the effect of an individual MZ twin's own achievement on their academic self-concept within and across domains. Thus, our finding verified the direct (rather than contrast) effects of siblings' achievement on each other's academic self-concepts in the family context. Accordingly, the current finding newly suggests that a sibling's achievement is an important frame of reference for a child's academic self-concepts within and across domains.

From the perspective held in the sibling literature, a direct (rather than a contrast) effect of a co-twin's achievement on an MZ twin's academic self-concept showed assimilation and social learning processes within a sibling pair by which siblings use each other as a model for social learning to imitate and assimilate with each other throughout their development (Bandura, 1989). In this regard, MZ twins provided empirical evidence for how an individual child constructs their academic self-concept by using their very similar sibling's academic achievement as a model for learning. By contrast, DZ twins showed sibling nonreferencing or sibling deidentification (Whiteman et al., 2007; Whiteman, McHale, et al., 2011) such that they individually constructed their own academic self-concept independent of their sibling's achievement.

Alternatively, our finding can be taken as new evidence of school-aged twins' academic socialization with their co-twins. It has been suggested that constant companionship with co-twins may result in either great closeness/assimilation of behaviors and traits within twin pairs, or twins may strive for separate identities and sibling deidentification (Schachter et al., 1978; Schachter et al., 1976). Generally, MZ twins were reported to be close to each other, whereas DZ twins were more concerned with their own individual rights and greater sibling rivalry (Furman & Lanthier, 2002). Considering that assimilation was observed in MZ twins but not in DZ twins, the current finding of academic social comparisons in twins may be viewed as an impressive corroboration of previous theories and findings that explained MZ twins' very special relationship with their co-twin (Fraley & Tancredy, 2012; Tancredy & Fraley, 2006). This leaves open the question of whether current findings on strong assimilation with a sibling's achievement occur in nontwin sibling pairs.

Overall, the findings from the third study showed how an individual child's achievement serves as a frame of reference for their own academic self-concept as well as their sibling's academic self-concept within and across domains, thus incorporating social and dimensional comparison processes (Marsh, 1986b). Thus, the findings showed how children use diverse frames of reference to construct their academic self-concept not only in school but also at home. Accordingly, the third study provided support for the effects of an individual child's achievement on their sibling's academic self-concept as proposed by expectancy-value theory's model of family influences (Eccles, 2007). In addition, the current findings provided evidence for the diverse effects of siblings' social learning, sibling deidentification, or nonreferencing on an individual child's academic self-concept by comparing different types of sibling pairs. On the basis of our findings, individual children are seen as active agents

of their own educational development by evaluating their own achievements in school and looking at their siblings' achievements at home to construct their own academic self-concepts within and across domains.

6.1.3. Children's Effects on Parents

Effects of Individual Children's Achievement on Parents' Beliefs

Whereas many prior studies have drawn on parents' beliefs and practices as predictors of children's achievement (Boonk et al., 2018; Fan & Chen, 2001; Jeynes, 2003, 2007), by contrast, we focused on children's effects on parents. Beyond the general comparison of the child-parent relationship in different families, we focused on academic socialization within families with more than one child. Accordingly, we considered an individual child's and their sibling's concurrent influences on their parents' child-specific beliefs and support in line with the expected effects of children's and siblings' characteristics on parents' beliefs and behaviors in the model of family influences by Eccles and colleagues (Eccles, 2007; Eccles, Arberton, et al., 1993). On the basis of this model, we addressed how parents' beliefs about children's academic abilities and parental support are diversified across siblings.

The first study showed how older and younger children's achievement affects each mother's and father's beliefs about each sibling's academic abilities within and across academic domains. Individual siblings' higher academic achievement predicted a mother's and father's higher beliefs about each child's academic abilities within each academic domain of math and German, controlling for children's sex, age, the age difference between siblings, the constellation of siblings' biological sex, and siblings' achievement. Not only did an individual child's achievement in a respective domain have an impact, but the child's achievement in the other domain also had an impact on the mother's and father's beliefs about the child's academic ability in the first domain. However, a younger child's German achievement had a negative effect on the mother's beliefs about the child's math ability, whereas the child's math achievement had a positive effect on the mother's and father's beliefs about the child's ability in German. The inconsistent pattern in the results may have resulted from parents' less differentiated beliefs about the child's academic abilities across domains as shown in the strong correlations of parents' beliefs across academic domains for younger children. It may also be related to computing the analysis with a small sample of 95 families. Thus, a careful interpretation of the results is needed.

Nevertheless, the overall significant effects of an individual child's achievement on the mother's and father's beliefs highlighted parents' child-specific beliefs as hypothesized in expectancy-value theory's model of family influences (Eccles, 2007; Eccles et al., 1983). Yet, by employing the I/E model(Marsh, 1986b), the current findings further verified the domain-specific structure of parents'

beliefs about each sibling's academic ability influenced by each individual child's achievements in different academic domains. Like children's academic self-concepts, parents' beliefs about children's academic abilities were domain-specific, and the formation of parents' beliefs about children's academic abilities was in accordance with children's formation of their own academic self-concepts (Marsh, 1990c; Marsh et al., 1988). According to our findings, parents' beliefs are domain- and child-specific as claimed in the viewpoint from expectancy-value theory (Eccles, 2007; Eccles, Arberton, et al., 1993; Wigfield et al., 2015).

Interestingly, in the first study, an individual child's achievement had an impact on parents' beliefs about the sibling's academic ability independent of the sibling's own academic achievement. Specifically, the younger child's math achievement had a robust effect on the father's beliefs about the older child's math ability while controlling for the younger- and the older child's sex, age, the age difference between siblings, and siblings' biological sex constellation, and the older child's own math and German achievement. This brings new insights into an individual child's achievement as having a cross-sibling influence on the father's beliefs about the other child's math ability, thus supporting the sibling modeling hypothesis that siblings serve as a frame of reference for parents' beliefs and support for the other child (Whiteman & Buchanan, 2002). Yet, the current findings showed that the younger child's achievement served as the frame of reference for the father's beliefs about the older child's achievement in contrast with the previous empirical findings, which suggested a hierarchy within families that first-born children were generally regarded as referents for second-born children (Jensen & McHale, 2017; Whiteman & Buchanan, 2002; Whiteman et al., 2003). Given that younger children generally have lower academic achievement than older ones as reported by an empirical finding based on large samples (e.g., Conley et al., 2007), fathers might have set the younger child's academic achievement as a threshold for evaluating both siblings' general academic ability.

Reciprocal Effects Between Learning Motivation and Parental Support

The second study showed a reciprocal association between individual children's learning motivation and parents' child-specific learning encouragement from age 11 to age 13, holding individual children's sex, personality traits, school grades, and family SES constant. This means that the effect was from parents' learning encouragement to each child's learning motivation and from each child's learning motivation to parents' learning encouragement and was thus bidirectional. As hypothesized in the transactional model of family influences (Bell, 1968; Sameroff, 2009), each child and each parent co-created the encouraging learning environment to further reinforce the child's autonomous learning. This finding especially highlights children's learning motivation as the facilitator of parents' encouragement for children's autonomous learning to set goals and ask questions in school. Thus, children's communication of their learning motivation to their parents is important for receiving favorable parental support for children's autonomous learning. Along with prior findings on the

reciprocal effects between parental involvement and expectations and children's academic functioning and achievement (Briley et al., 2014; Dumont et al., 2014), our findings enhance our understanding of how and why parents support their children in the educational process. Overall, the current findings call for a new way of viewing educational influences between parents and children in which both are considered agents.

To understand how the reciprocal association between children's learning motivation and parents' learning encouragement plays out in the family context, we investigated the association in both within-twin-pair regressions and between-twin-pair regressions. The reciprocal association was found only in within-twin-pair regressions but not in between-twin-pair regressions. This means that a child's higher motivation than their sibling at age 11 predicted their perception of higher learning encouragement from parents at age 13, and a child who received higher learning encouragement from parents than their sibling at age 11 had higher learning motivation at age 13. Yet, there was no difference in the reciprocal association across different families because no effects were found in the between-twin-pair regressions. The significant effect found in the within-twin-pair regressions brings new insights into how the transactional influences between a parent and each child differentiate siblings' learning environments in the family and their learning motivation across the 2 years. Accordingly, this finding highlights the motivational dynamic within the family and illuminates interactive influences between each child and their parent.

On the other hand, this finding may also indicate a larger gap between sibling differences in their learning motivation throughout their individual experiences with parental support in the family. Along with the reciprocal effect between an individual child's learning motivation and their perception of parents' learning encouragement, an individual child's learning motivation at age 11 predicted parents' emotional support at age 13 in within-twin-pair regressions. This means that a child who had higher learning motivation than their sibling at age 11 perceived higher emotional support from parents at age 13. Whereas this finding points to the importance of an individual child's endeavor to have high learning motivation to receive more favorable support from their parents, a child who has lower motivation may have needed more learning encouragement and emotional support from their parents than their sibling did. Given that both learning encouragement and emotional support from parents positively affect individual children's achievement motivation (Pomerantz et al., 2012), the current empirical finding provides insights into how parents should provide better support for lower achieving siblings' learning motivation.

Although we addressed diverse dimensions of parental support, including parents' expectations, parents' emotional support, parents' learning encouragement, and parental control, the reciprocal association with children's learning motivation was observed only for parents' learning

encouragement. However, this seemingly disappointing result supported the claim that children's internalization of the value of intrinsic learning depends on parenting methods (Grusec & Goodnow, 1994). The exclusive reciprocal effects found between parents' learning encouragement and children's learning motivation are comparable to and in line with Pomerantz and colleague's (Pomerantz, Grolnick, et al., 2005) viewpoints, which emphasized that parents' support for children's autonomous learning (e.g., a mother's emphasis on effort and learning strategies) is particularly important for children to feel socially supported and competent. Based on the importance of providing the social support that is aimed at satisfying the children's sense of competence, autonomy, and relatedness to foster intrinsic, autonomous learning motivation (Deci, 1975; Deci & Ryan, 2000; Grolnick et al., 1997; Grolnick et al., 1991; Ryan & Deci, 2000), the dimensions of parental support should be carefully considered. In this regard, the current findings highlight the importance of providing parental learning encouragement for individual children's autonomous learning motivation.

The other important findings of the second study were the substantial effects of children's personality traits, school grades, and sex on the association between differential parental support and children's learning motivation within and between families. Overall, children's higher levels of conscientiousness and openness were related to their higher perceptions of parental support, whereas their higher levels of neuroticism were related to their lower perceptions of parental support in the learning context. On the other hand, children's higher levels of openness and conscientiousness were also related to their higher learning motivation. It could have been either that parents considered each child's personality traits when they provided learning support for individual children or that siblings with a certain personality type might tend to perceive parental support as higher than siblings with other personality characteristics. For whichever reason, as we found effects of children's personality on the association between perceived parental support and children's learning motivation, these findings have consistently shown how important it is to consider children's personality traits as potential factors that contribute to the dynamics of academic socialization within the family. Along with children's personality traits, children who achieved higher school grades perceived lower parental support than their siblings. In addition, female MZ and DZ twins tended to have a higher perception of their parents' learning encouragement and a lower perception of parental control than male twins, thus signaling parental gender stereotypes as hypothesized in expectancy-value theory's model of family influences (Eccles, Arberton, et al., 1993). In this regard, there is a need for more studies in which individual children's diverse characteristics are taken into account when investigating academic socialization between children and parents (Eccles, Arberton, et al., 1993) as was done in the present dissertation.

6.1.4. Effects of Sibling Resemblance

On the basis of effects of characteristics of individual children on parents' child-specific beliefs and support as well as their educational development (Eccles, 2007; Eccles et al., 1983), the current dissertation took a further look at what happens if siblings are very similar to each other. Drawing from social comparison theory (Festinger, 1954), sibling resemblance was hypothesized to amplify potential assimilation and social learning within twin pairs and the extent to which parents perceive siblings as similar and associate the siblings. Accordingly, we tested effects of sibling resemblance on the comparison processes within sibling pairs and parents' similar/different support for the siblings by comparing MZ and DZ twin pairs because MZ and DZ twins differ in the extents to which their genetics and characteristics are similar (for a meta-analysis, see McCartney et al., 1990).

The second and third studies in the dissertation showed substantial effects of sibling resemblance on academic socialization within the family. In the third study, MZ and DZ twins showed significant differences in effects of co-twin's achievement on individual twin's academic self-concept within and across domains. Specifically, MZ twins showed the assumed assimilation from direct (rather than contrast) effects of their co-twin's achievement on an individual twin's academic self-concepts within and across domains. Despite being very similar and close to each other, DZ twins showed sibling nonreferencing or deidentifcation, such that they individually constructed their academic self-concepts independent of their co-twin's achievement.

The contrasting results in MZ and DZ twins address an interesting question of whether a sibling pair's similar or different characteristics foster sibling comparison processes or whether the sibling comparison process shapes a sibling pair's similar/different characteristics. In view of the influence of siblings on educational development, many prior theories and literatures have assumed that diverse comparison processes in siblings, such as deidentification and social learning, should help siblings develop similar or different attributes, attitudes, and behaviors (Whiteman et al., 2009; Whiteman et al., 2007). By contrast, the current findings showed that siblings' social learning or deidentification differed by a sibling pair's overall similarity/dissimilarity. More specifically, we found that very similar siblings (MZ twins) were more likely to show social learning, whereas less similar siblings (DZ twins) were more likely to show nonreferencing and deidenfication in the educational context. In this regard, the present findings newly suggest that a sibling pair's overall similarity is a potential moderator of effects of sibling comparisons on their academic self-concepts.

Correspondingly, sibling resemblance had an impact on siblings' academic socialization with their parents. In the second study, the reciprocal association between individual children's learning motivation and parents' learning encouragement was found only in within-DZ-pair regressions but not for MZ twins. When explicitly tested, MZ and DZ twins especially differed in effects of individual

children's learning motivation on their perceptions of parents' learning encouragement. Simply put, only the sibling pairs who moderately resembled each other (DZ twins) perceived that their individual interactions with their parents were influenced by their sibling's different level of learning motivation, whereas the very similar sibling pairs (MZ twins) did not perceive this difference in their interactions with their parents. Given that parents tend to hold more similar expectations (Scarr, 1982) and more similar perceptions of their MZ twin offspring than DZ twin offspring (Reiss, 2003), parents might have encouraged MZ twins' learning more similarly than for DZ twins in line with the previous empirical findings that reported more similarity in parents' treatment of MZ than DZ twins (Lytton, 1977; Morris-Yates et al., 1990; Rowe, 1981). Nevertheless, the cause of MZ and DZ twins' differential perceptions of parental support is not yet clear. It is possible that the greater similarity of MZ twins triggered more similarity in their learning environments at home (Scarr, 1982; Scarr & Carter-Saltzman, 1979), such that parents may have supported MZ twins' learning more similarly. On the other hand, it is also possible that MZ twins may have attended to more similar aspects of their environment (Scarr, 1982; Scarr & Carter-Saltzman, 1979), such that they perceived their parents more similarly. Either way, differences in MZ and DZ twins' academic socialization with their parents suggest that sibling resemblance is an influential moderator of siblings' similar or different experiences with parental support.

Overall, the differences between MZ and DZ twins consistently found in the second and third studies are of high theoretical interest as they can inform research on effects of sibling resemblance on the extents to which parents similarly or differently support siblings and how siblings interact with each other in the learning situation. The differences in academic socialization between MZ and DZ twins highlight individuals' intrinsic tendency to evaluate themselves on the basis of how they perceive others, especially those they perceive as similar and close to themselves, and their tendency to evaluate others for similarity as claimed by social comparison theory (Festinger, 1954). In this regard, our findings provide insights into the dynamic interplay between sibling resemblance and different intrafamilial influences. Perhaps the expected effects of sibling characteristics on academic socialization in the family from expectancy-value theory's model of family influences (Eccles, Arberton, et al., 1993) will now gain more attention on the basis of our findings.

Alternatively, when viewed from the perspective of academic self-concept research, our finding of differential co-twin achievement effects in MZ and DZ twins may offer information about individual differences in the formation of academic self-concept. On the basis of our finding, it could be assumed that if a student compared themself with an "other" who was perceived to be extremely similar, which is the case for MZ twins, they would experience a direct effect of the similar other's achievement on their academic self-concept. Like looking in the mirror, MZ twins showed parallel patterns in effects of their achievement and their co-twin's achievement on their academic self-

concepts within and across domains. As these assimilation effects were exclusively found in MZ twins but not in DZ twins despite being similar, we conceptualized that the observed pattern of results is a mirror effect from the exceptionally close similarity within MZ twin pairs. The mirror effect in MZ twins provides new evidence for assimilation effects within extremely similar comparison targets. Whereas most prior research on social comparisons among students has typically shown a negative effect of social contrasts on academic self-concept (Marsh, 1987; Marsh et al., 2004), our finding of a mirror effect suggests that individual students' perceptions of a comparison target should be considered as an important moderating factor for differentiating positive effects of social comparisons on individual students' academic self-concepts.

6.2. Theoretical Implications

Grounded in the model proposed by Eccles and colleagues (Eccles, Arberton, et al., 1993), we further designed the three studies to incorporate diverse theories, such as the I/E model (Marsh, 1986b), the transactional theory of family influences (Kuczynski & Parkin, 2007; Sameroff, 1994, 2009), and social comparison theory (Festinger, 1954). Accordingly, the three empirical studies in the present dissertation showed that the diverse theories have strong relevance to expectancy-value theory's model of family influences (Eccles, Arberton, et al., 1993). Indeed, by taking an interdisciplinary approach, the current dissertation makes important contributions by incorporating new complex patterns into the model suggested by Eccles and colleagues (Eccles, Arberton, et al., 1993). More specifically, in the studies in the current dissertation, the I/E model (Marsh, 1986b) was applied to investigate effects of individual children's achievement on parents' child-specific beliefs, and thereby, we verified within- and between-domain influences on parents' beliefs and newly showed a cross-sibling influence that an individual child's achievement affected parents' beliefs about their sibling's academic ability. By conducting research that was based on the transactional theory framework, we further identified how parental support differed by differences between siblings in achievement motivation. By incorporating social comparison theory (Festinger, 1954) into the present studies, we were able to gain new insights into the effects of sibling resemblance on parents' support of siblings and the siblings' interactions. Accordingly, the newly identified patterns in the studies included in the current dissertation brought a more precise understanding of the dynamics of academic socialization within the family, thus contributing to deeper insights into expectancy-value theory's model of family influences (Eccles, Arberton, et al., 1993).

6.3. Methodological Implications

The first study suggested a systematic way to define parents' beliefs by considering the diverse levels of intrafamilial influences. To date, many prior studies have conceptualized parents' beliefs at

only the very general level, and therefore, we had only an ambiguous and incoherent understanding of parents' beliefs across these previous studies. Some studies took a response from one parent to represent the parental beliefs for the family (Dai, 2002; Van Zanden et al., 2017), whereas others aggregated the two parents' responses and used that aggregrated belief as a general parental belief of the family (Wolff et al., 2020). Thus, parents' beliefs have not been coherently conceptualized and investigated across studies. Given that substantial variability in parents' beliefs was found at each level of influence within a family in the first study, the current dissertation calls attention to the precise conceptualization of parents' beliefs for theoretical and empirical advances in investigations of parents' beliefs.

We suggested a way to investigate cross-sibling influences on parents by applying the I/E model. In previous studies, the I/E model has typically been applied to investigate individual students' formation of academic self-concepts in the school context. In our studies, we modeled an individual child's own achievement along with their sibling's achievement as predictors of parents' beliefs about each child's academic ability within and across academic domains based on the I/E model. Accordingly, we found that an individual child's achievement is used as an additional frame of reference for parents' beliefs about the sibling's academic capacities within and across domains. On the basis of our findings, we suggest that the I/E model be used to investigate the cross-sibling influence of siblings' achievement on parents' beliefs about each child's academic abilities.

We showed the usefulness of conducting research using twin data to investigate influences of parental support and sibling interactions within and between sibling pairs. Unlike the general belief that twin data should be used to investigate "twins," our empirical findings support the suggestion made by behavioral geneticists (Asbury et al., 2003; Daniels & Plomin, 1985; Dunn & Plomin, 1990; Turkheimer & Harden, 2014; Turkheimer & Waldron, 2000) that twin data allow researchers to compare sibling differences in their perceptions of learning experience and educational development by holding children's characteristics, such as age, birth order, and sex, constant. In the second study, we ran cross-lagged modeling in within-twin-pair regressions and between-twin-pair regressions and showed that the reciprocal association between an individual child's learning motivation and their perception of parental support differed between siblings. Consequently, we suggested a way to investigate the association between sibling differences in their educational development and their differential experiences within the family.

In addition, although MZ and DZ twin data have typically been used to compare heritability and environmental influences on individual children's traits, the current dissertation compared MZ and DZ twins to investigate effects of sibling resemblance on their educational development. The multiple-group analyses with zygosity as a grouping variable showed how the effects of families' dynamics and characteristics on individual children differed between very similar sibling pairs and less similar sibling

pairs. In particular, the different degrees of sibling similarity in MZ and DZ twins allowed us to test social comparison theory (Festinger, 1954) with respect to the role of interpersonal similarity in social assimilation in a real-life setting beyond the lab environment. Given that parental support and sibling interactions differed between MZ and DZ twins, we would like to suggest more research to explore the moderating role of interpersonal similarity in academic socialization within the family.

6.4. Limitations

There were several limitations of the three studies included in the current dissertation. The studies had missing data for different reasons. The first study had data from a limited number of 95 families available for our analyses. This methodological limitation might have resulted in the inconsistent patterns in the social and dimensional comparison effects on parents' beliefs. Despite the small sample size, the data were rich in quality as they included the responses of all family members, which allowed us to investigate effects of both siblings' achievements on each parent's beliefs about each sibling's academic abilities within and between the domains by employing the I/E model (Marsh, 1986b). The second and third studies were conducted on a nationally representative sample of MZ and DZ twins that was uniquely well-suited to test within- and between-twin-pair regressions by holding siblings' sex and age constant. Nevertheless, the second study had missing data due to wave nonresponse, and thus, approximately 30% less data were available in the second wave of data collection than the data collected in the first wave in the Twinlife study. The third study had missing data due to the item nonresponse from students' school grades in the Twinlife study. More specifically, there were approximately 42% of 4,202 twins who did not submit a photo of their school grades. Yet, we substituted self-reported grades for the missing school grades so that we consequently reduced the missing data rate to 15%. The missing data in each study limited the generalizability of our studies, and our results should be interpreted with caution. Accordingly, we dealt with missing data by using a large number of covariates in the first and second studies and added a lot of auxiliary variables for the third study to make the MAR assumption more plausible. We further used FIML estimation in all studies (Graham, 2003).

Attention should be paid to the constructs we used in our studies. For instance, for the first and third studies, we used school grades as a proxy for achievement, rather than standardized tests. Thus, concern may arise about the lack of validity of school grades (e.g., Mattern et al., 2011). However, school grades are a visible and salient way for students to compare and evaluate their academic ability, and grades are given a lot of weight in placement decisions. Accordingly, it is standard procedure to use grades in studies on the I/E model. In the second study, the measurements of perceived parental support and children's learning motivation were based on students' self-reported answers only. Although parents' reports were not used, it is students' reports that have more validity because what

students think is more important than what parents say they do. In addition, given that our research focus centered on students' individual perceptions of parental support, the use of students' reports was justified. One should also carefully consider that the operationalization of the constructs in Study 2 was slightly different than in other studies. For instance, parents' expectations represented more of a parental expectation standard rather than parents' aspirations in other studies. On the one hand, the different operationalization of the constructs is a typical problem in research on motivation and education. Nevertheless, despite the slightly different operationalization of the construct in Study 2 from the other studies, the current findings addressed a different aspect of parents' expectations regarding the pressure that parents exert when imposing their standards on their children.

Even though our studies suffered from several limitations, we were able to address these limitations by applying reliable estimation methods, including covariates, and transparently describing each measure we used. Due to the limitations of the current studies, there are several suggestions for future studies. We would like to see more studies replicate our findings with less missing data and manage the additional analyses by including standardized academic tests (rather than school grades) and parents' reports of their support for their children and to see if the reciprocal effects are still consistently observed. Regarding the typical problems of using a different set of measures for motivation and education research in general, we would like to make a call for future studies in the field to establish a common set of measures so that findings can be compared across the studies.

6.5. Conclusion

Overall, the three studies in the current dissertation provide theoretical and empirical support for expectancy-value theory's model of family influences on children's motivation and achievement (Eccles, Arberton, et al., 1993). The current dissertation focused on the expected effects of an individual child's and their sibling's characteristics on academic socialization within the family in accordance with the I/E model (Eccles, Arberton, et al., 1993), which has gained relatively little attention in relevant studies and reviews of the model (Eccles, 2007; Wigfield et al., 2015).

Throughout the literature reviews, the present dissertation brought insights into how individual children's and their siblings' prior achievements and learning motivation, along with their personality traits, sex, and birth order, diversify children's individual experiences with their parents and interactions between siblings within the family, thus placing importance on the dynamics of academic socialization within the family.

The three studies in the dissertation presented empirical results that were in accordance with the four hypotheses: First, the dissertation presented empirical evidence that parents hold both child-specific and general beliefs about their children and provide both child-specific and general support for their children. Second, the dissertation showed that an individual child's achievement not only had an impact on their own academic self-concept but also their sibling's academic self-concept within and

between domains. Third, the dissertation showed effects of an individual child's achievement on parents' beliefs about the child's academic ability as well as their sibling's academic ability. The dissertation also showed a reciprocal association between an individual child's learning motivation and parents' learning support, which differed between siblings. Finally, the dissertation showed effects of sibling resemblance on their comparison processes and parental support for siblings. On the basis of these findings, individual children and their siblings are viewed as active agents of academic socialization within the family.

By taking an interdisciplinary approach, the dissertation showed the strong relevance of the I/E model (Marsh, 1986b), the transactional model of parental influence (Bell, 1968), and social comparison theory (Festinger, 1954) to the investigation and extension of expectancy-value theory's model of family influences (Eccles, Arberton, et al., 1993). From a methodological perspective, the empirical studies included in the current dissertation illustrated a coherent method for addressing complex patterns in academic socialization within the family. Accordingly, we suggested a systematic way to analyze the structure of parents' beliefs in accordance with multiple levels of intrafamilial influences, cross-sibling influences on the formation of parents' beliefs, the investigation of the reciprocal association within and between sibling pairs, and diverse research designs employing twin data. In these regards, the current dissertation makes a meaningful contribution to the theoretical and empirical advancement of studies on the dynamics of academic socialization within the family.

7. References

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