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Does sibling and twin similarity in cognitive ability differ by parents' education?

Abstract:

Stratification scholars predominantly investigate how differences among children from different families emerge and tend to neglect differences among children from the same family. I study sibling similarity in cognitive ability and examine whether their similarity varies by parents' education. Although economic approaches and their extensions argue that disadvantaged parents reinforce differences while advantaged parents compensate for differences, I argue that parents may also make equal investments and thus accept differences among their children. I refer to the literature on stratified parenting that demonstrates that parents are engaged differently in child-rearing and their children's skill formation processes. Because advantaged parents foster children's talents more individually compared with disadvantaged parents, I propose that sibling similarity is lower in advantaged than in disadvantaged families. Previous studies based on sibling correlations provide conflicting evidence. To account for observable and unobservable differences among siblings, I extend the established sibling correlation approach and study dizygotic and monozygotic twins in addition to siblings. The analyses draw on novel data from a population register-based study of twin families. I find that young adult siblings and twins are less alike in cognitive ability in highly educated families than in less educated families. Hence, my results support the hypothesis concerning equal investments and indicate that stratified parenting has a long-lasting influence on children's cognitive ability.

Key words: intergenerational transmission; educational inequality; cognitive ability; sibling correlations; twins; Germany

1. Introduction

The link between family background and children's education is well established in the literature (e.g., Breen 2010; Breen/Jonsson 2005; Torche 2015). Most of what we know about the impact of family background influences derives from studies that examine children from different families. Yet, a smaller body of literature studies differences that emerge among children from the same family. These studies highlight that shared family background influences, such as parents' education, occupation or income, do not affect siblings equally. Indeed, for most stratification outcomes, including education, siblings



correlate at about 0.5 (e.g., Downey 1995; Hauser/Wong 1989; Sieben/Huinink/De Graaf 2001). Thus, stratification mechanisms run not only between families but also within the family itself: despite being exposed to fairly similar family conditions, siblings end up with different levels of education. This challenges the common – though mostly not explicitly stated – assumption that shared family influences affect children in similar fashion (e.g., Conley 2008; Diewald et al. 2015).

An emerging scholarship investigates whether the similarity of siblings varies depending on parents' social background (e.g., Conley 2008; Conley/Glauber 2008; Conley/Pfeiffer/Velez 2007; Grätz 2018). Despite excellent research in this field, studies do not explicitly take into account the fact that differences among siblings are not only the result of parents' social background and associated resources but are also driven by differences in genetic make-up. Behavioral genetics provides consistent evidence that genes are an important source of individual differences and that they can shape reactions to and from the social environment (e.g., Freese 2008; Polderman et al. 2015). To understand why differences among siblings emerge, it is therefore important to consider genetic heterogeneity as well. I build on previous studies on a possible stratification of sibling similarity and study sibling and twin similarity in cognitive ability, which is highly predictive of educational success and is strongly influenced by genes (e.g., Polderman et al. 2015).

Current explanations for within-family differences are mainly rooted in economic perspectives that model parents' investment decisions within the household (Becker/Tomes 1976; Behrman/Pollak/Taubman 1982). Adding a stratification aspect, Conley (2004, 2008) proposes that advantaged parents are more likely to invest in a way that compensates for differences among their children, whereas disadvantaged parents reinforce differences due to efficiency considerations. I argue, however, that parents might also invest equally in their children and thus accept differences among them. I draw on the literature on stratified parenting, which originally emphasized the role of parenting in the emergence of differences between families and propose that differences in parenting also influence the extent to which siblings resemble one another (e.g., Cheadle/Amato 2011; Kalil/Ryan/Corey 2012; Lareau 2011; Lareau/Weininger 2003). Lareau differentiates between two logics of parenting (2011). Disadvantaged parents are engaged in a parenting concept referred to as "natural growth" and intervene little in their children's skill formation processes. Because resources are limited, parents more often invest primarily to meet the basic needs of their children. Advantaged parents, by contrast, have more resources and can afford investments in addition to those needed fundamentally. They engage in a parenting concept referred to as "concerted cultivation" and intend to further skills and behaviors typically found in higher class families. Importantly, parents embrace an active parenting strategy that shapes developmental processes of their children. Over and above "concerted cultivation" in accordance with higher class habits such active investments can also address children's individual potentials and needs. Such investments are more child-specific. Because children develop depending on their unique interests, talents, and related specific inputs, I expect them to end up being less alike in their cognitive ability than siblings from disadvantaged backgrounds. Hence, I propose a competing hypothesis – namely, that siblings are less similar in terms of cognitive ability in advantaged families than in disadvantaged families.

Previous research on sibling similarity (i.e., sibling correlations) in cognitive skills is limited and provides conflicting evidence (Anger/Schnitzlein 2017; Conley/Pfeiffer/Velez

2007; Grätz 2018). Yet, findings on sibling correlations have recently been criticized (e.g., Björklund/Jäntti 2012): First, (full) siblings differ in age and, because family contexts are not necessarily stable over time, might grow up in different family environments. Second, (full) siblings differ in their genetic make-up. Consequently, findings concerning the link between parents' social background and the similarity of siblings might be influenced by developmental differences, genetic differences, and/or a combination of the two – and are not necessarily the direct consequence of varying parental resources.

To address this shortcoming, I study the similarity of (full) siblings, dizygotic (DZ), and monozygotic (MZ) twins. DZ twins are born at the same time and thus share much more of the family influences than (full) siblings do. However, DZ twins differ in their genetic make-up, which also affects the degree of similarity. MZ twins, by contrast, are genetically alike. The similarity between MZ twins therefore captures family influences most comprehensively. MZ twins allow one a) to accurately differentiate between shared family and child-specific influences and b) to rigorously test whether the similarity changes if parents' education increases.

Sibling and twin similarity is estimated with multilevel models. I draw on the newly collected dataset from the TwinLife study. TwinLife is a population register-based sample of more than 4,000 twins and their families residing in Germany (Diewald et al. 2017). Unlike many observational twin studies, TwinLife has applied a probability-based sampling strategy. These data make it possible to investigate, for the first time for Germany, sibling and twin similarity in cognitive ability and a possible stratification covering a broad range of the social spectrum (Lang/Kottwitz 2017).

I contribute to the literature by acknowledging that family influences comprise both social resources and genetic transmission. In addition, I control for the relationship of siblings and twins, which addresses a major limitation of studies analyzing within-family stratification. This enables me to model family influences more comprehensively and to analyze systematic differences in the similarity of siblings that are not influenced by differences in the rearing environment, genetic influences or even the sibling relationship. Finally, I extend current theoretical explanations based on economic investment and emphasize the role of stratified parenting instead.

2. Theoretical background

How can we explain differences in cognitive ability among children from the same family? And do differences vary according to parents' social background? To address these questions, I apply a within-family perspective and link parents' investments and parenting to sibling similarity. I then refer to the sibling correlation framework, which is widely applied to test the proposed mechanisms indirectly. Incorporating findings from behavioral genetics, I argue that twins as opposed to siblings provide a more suitable unit of analysis to test whether a change in similarity is associated with parents' social background.

2.1 *Sibling similarity and parents' investments*

To explain how differences among children from the same family emerge, scholars predominantly refer to economic perspectives that model parents' resource allocation decisions within the household. Becker and Tomes (1976) propose a general model according to which parents rationally invest various types of resources in children's human capital formation and, thus, in later-life outcomes. Following the investment paradigm, parents aim to maximize the total returns of the household. Accordingly, their investment decisions are driven by efficiency considerations, and resources are directed to the child from whom they anticipate the highest returns. Later in the life course, parents seek to create equality among children by monetary transfers. According to the "efficiency paradigm", parents purposely reinforce differences in human capital, which increases differences among their children.

Behrman and colleagues (1982) counter this perspective and add a different motivational aspect of parents' investments decisions. Because future returns on investment are uncertain, parents seek to compensate differences among children and tend to create equal outcomes in children's human capital. Thus, parental investments actively reduce differences among siblings, leading to higher sibling similarity with respect to education and, presumably, later income. This ultimately reduces the need to make monetary transfers in order to create equal living standards for their children. In this sense, parents invest in exactly the opposite way from that predicted by Becker and Tomes (see also Conley 2008).

Thus, in both perspectives, parents allocate their resources unequally among their children: If their decision is guided by efficiency considerations, parents increase differences among their children by favoring the most promising child (lower similarity). If, on the other hand, parents intend to create equal outcomes, they compensate for differences and favor the less talented child (higher similarity).

Parents' investments and social background

It is also important to take into account the fact that the quality and quantity of parents' investments might differ depending on their social background. According to the family investment model (FIM), which extends the investment paradigm, advantaged parents have more resources that are conducive to cognitive and noncognitive skill development than do disadvantaged parents (e.g., Conger/Conger/Martin 2010). Resources include not only various goods and services, such as better housing and healthy food, but also skill-enhancing activities and a stimulating home environment (e.g., Cunha/Heckman 2007; Cunha et al. 2006). The family stress model (FSM) focuses on the influence of intra-family dynamics and marital conflicts triggered by economic hardship; due to increased levels of psychological stress, disadvantaged parents become less involved in their children's affairs, are less capable of meeting their children's emotional needs, and often respond with harsh parenting (e.g., Conger/Elder 1994; Conger/Conger/Martin 2010). The related nonmaterial consequences of financial strain are the relevant pathways through which parents' social position influence children's skills and well-being. Both the family investment model and the family stress model have made major contributions to our understanding of how parents' social background leads to systematic differences between

children from advantaged and disadvantaged families. Nonetheless, whether and how parents' social background leads to differences or similarity among children from the same family remains unclear.

Conley (2004, 2008) adopts a within-family perspective and links parents' social background to their resource allocation decisions. He argues that parents' investment rationale is contingent on their social position: Depending on the resources available, parents invest either in a compensatory fashion or in line with the efficiency paradigm. Accordingly, parents with fewer resources minimize the risk of failure by directing resources to the most promising children, whereas advantaged parents can afford both – investments in the most promising child and compensatory investments in the less gifted one. In this perspective, equality among siblings is a goal that can be attained once enough resources are available (higher sibling similarity); otherwise, parents will have to pick one of their children and direct their resources selectively (lower sibling similarity) (Conley 2004).

However, parents might also make equal investments and accept that their children develop differently. To elaborate how equal investments might accentuate differences between children from the same family, I draw on the literature on stratified parenting. Broadly speaking, parenting refers to parent-child interactions that affect children's development. Hereby, we can distinguish between parenting goals, parenting styles, and parenting practices (Darling/Steinberg 1993). Parenting goals, or socialization goals, refer to the outcomes that parents seek for their children. Parenting styles denote the emotional climate in which parent-child interactions are embedded, and parenting practices refer to parental actions and activities that parents provide for their children in order to achieve their goals. The study of parenting styles has a long research tradition among developmental psychologists pioneered by Baumrind (1971), whilst recent sociological studies focus on parents' activities, i.e. parenting practices, as expression of distinct cultural taste (e.g., Chedale/Amato 2011; Kalil/Ryan/Corey 2012; Lareau 2011; Lareau/Weininger 2003).

In her qualitative study, Lareau (2011) identifies two different logics of parenting that describe systematic differences in child-rearing and involvement in children's skill formation processes. These logics are rooted in the parents' distinct cultural practices and habits and influence children's skills, educational attainment, and hence their subsequent life chances.

Advantaged parents adopt a parenting concept referred to as "concerted cultivation." Parents seek to promote – that is, cultivate – their children's unique talents and to give them the ability to speak up for themselves in order to increase their chances of later-life success. To achieve this, parents invest various types of resources that support the skill development of their children. Importantly, parents actively shape the development of their children and plan interactions and activities with their children. Parents are very controlling paired with responsiveness. Parents provide clear guidance and are strongly involved in structuring their children's daily lives. Consequently, children grow up in a home environment in which the parents structure their leisure time and actively further their children's interests. To be effective (i.e., to foster the children's talents), such parents provide child-specific inputs: they customize their children's daily activities in line with the children's interests; they monitor the children's educational processes individually; and they provide support if needed. Hence, stimulating activities and resources are

provided for every child, but what kind of investment each child receives will depend on their specific needs.

Disadvantaged parents adopt a parenting concept referred to as “natural growth”. Here, the children’s development is perceived more as something that naturally evolves over time. Parents intervene less in the developmental processes of their children and provide those inputs that are fundamentally needed for development. Parents are less involved and more authoritarian, set strict rules which are not questioned. Due to limitations of time and money, parents often lack the capacity to discover their children’s individual talents and/or to provide stimulating activities or resources to further those interests. Consequently, such parents adopt a less active role in their children’s development and skill formation. Disadvantaged parents also provide their resources for all of their children; investments are, however, rather uniform and thus less child-centered.

Quantitative studies provide support for different parenting concepts in line with Lareau’s notion on different logics of parenting (e.g., Cheadle 2008; Cheadle/Amato 2011) and their association with children’s academic performance (Bodovski/Farkas 2008; Roksa/Potter 2011) and facets of personality (Kaiser/Diewald 2014; Kaiser 2017). It is important to note that Lareau does not adopt a within-family perspective; rather, she shows how culturalized habits lead to systematic differences between advantaged and disadvantaged children. Furthermore, the notion of stratified logics of parenting is not mutually exclusive from either the family investment perspective or the family stress perspective. In fact, Lareau’s notion of different logics of parenting is supported by the finding that more advantaged parents provide more skill-enhancing inputs compared with disadvantaged parents (e.g., Conger/Conger/Martin 2010). Related to that, psychological stress as proposed by the family stress model (e.g., Conger/Elder 1994; Conger/Conger/Martin 2010) might provide a mechanism that explains why disadvantaged children receive less attention from their parents. Nonetheless, I argue that an important mechanism behind the emergence of within-family differences is rooted in active and strategic parenting behaviors found in advantaged families: Parents that seek to cultivate distinct skills and behaviors are also more actively involved in shaping the development of their children. Such investments can address children’s potentials and needs more individually which promote differences in cognitive ability among siblings to a greater extent (lower sibling similarity) than investments from disadvantaged parents. Disadvantaged parents often lack the capacity and/or resources to make those skill-enhancing investments and provide fairly uniform inputs, which leads to higher similarity. That siblings in advantaged families end up being more different than siblings in disadvantaged families is not intentional – it is a side effect of parents’ distinct parenting behavior.

Taken together, the literature provides competing hypotheses for a stratification of sibling similarity. Conley (2004, 2008) argues that parents allocate their resources selectively: If resources are limited, parents will allocate their resources efficiently; if resources are not restricted, parents tend to compensate. If Conley’s argument holds, I expect *siblings to be less similar in disadvantaged families compared with siblings from advantaged families (H1)*. If, however, parents make equal investments and adopt different parenting concepts, I expect the opposite pattern – that is, I expect *siblings to be more similar in disadvantaged families compared with siblings from advantaged families (H2)*.

2.2 *Previous findings*

The link between social background and sibling similarity has been studied for socioeconomic outcomes such as education, income, and earnings (Conley/Glauber 2008; Conley 2008), as well as for cognitive and noncognitive skills (Anger/Schnitzlein 2017; Conley/Pfeiffer/Velez 2007; Grätz 2018). Most studies refer to the US, although more recent studies have been conducted for Germany. Given that educational decisions are different from investments that further the development of cognitive ability (Boudon 1974; Breen/Goldthorpe 1997; Erikson/Jonsson 1996), in the following I focus on studies that analyze sibling similarity in cognitive and noncognitive skills. Conley, Pfeiffer and Velez (2007) analyzed sibling similarity in cognitive skills and behavioral outcomes during early childhood (between ages 6 and 12) based on the Panel Study of Income Dynamics (PSID) for the US. These authors used literacy, numeracy, reading comprehension, and problem-solving skills as indicators of cognitive skills, and the Behavior Problem Index (BPI) for behavioral outcomes; social background was approximated using mothers' education. The results offer some support for a systematic variation according to social background: Sibling similarity in literacy and the BPI was significantly higher for siblings whose mothers were less educated. Anger and Schnitzlein (2017) examined sibling similarity in cognitive ability, noncognitive skills (i.e., the Big Five), and locus of control for adult siblings (aged between 20 and 54) in Germany using the Socio-Economic Panel study (SOEP). Because they had only small sample sizes, they examined the link with social background only for noncognitive skills. The results show that sibling similarity for most indicators of noncognitive skills was higher for siblings whose mothers are more educated. Grätz (2018) examined sibling similarity in cognitive ability for young adult siblings (aged between 17 and 28) based on the SOEP as well. He used more recent waves and examined systematic differences in the similarity of cognitive skills according to social background, as indicated by parents' education, occupation, and social class (based on the Erikson-Goldthorpe-Portocarero social class scheme, EGP). Regardless of the indicator of social background, sibling similarity did not change systematically according to social background.

In sum, the empirical literature provides conflicting evidence for the country and the outcome under study. In the US, sibling similarity in the BPI and in literacy skills tend to be higher in disadvantaged families. For Germany, however, sibling similarity in noncognitive skills tend to be higher in advantaged families. Sibling similarity in cognitive skills, by contrast, did not systematically differ.

There are two factors that might explain why these findings diverge between the US and Germany. First, institutional differences might play a role. Germany and the US vary greatly in the institutional set-up of the welfare state. Social inequality is much more polarized in the US context, and the welfare state there is less invasive and provides only a weak insurance structure. The German welfare state, by contrast, provides more generous social benefits and a safety net. At least regarding cognitive skills, evidence for the US shows that poverty is strongly linked to children's cognitive outcomes, which is less so in Germany (Biedinger 2011). Thus, the fact that sibling similarity in literacy skills in the US is associated with social background might be explained by differences in marginalization that are experienced in these two countries (see also Schulz et al. 2017). Yet, evi-

dence for a systematic variation in cognitive outcomes is weak, because it was found for only one indicator of cognitive skills during early childhood. In addition, it is striking that the pattern identified for noncognitive skills tends in the opposite direction.

The second important factor that might explain the divergent findings is the age range of the siblings, which is closely linked to the development of cognitive and noncognitive skills (e.g., Cunha/Heckman 2007; Haworth et al. 2010). The two studies for Germany analyzed young adult siblings, whereas the study for the US analyzed siblings during childhood. Given that children are more sensitive to environmental influences (i.e., family inputs) during childhood (e.g., Cunha/Heckman 2007), divergent findings might indicate that the influence of parents' social background varies over the children's life courses. However, this remains an empirical question and will require more research that also takes children's developmental stage into consideration.

A major limitation of previous studies, besides possible life course variation, is that they have not sufficiently accounted for genetic influences. Genetically sensitive studies provide consistent evidence that cognitive and noncognitive skills, as well as more distal outcomes such as achievement scores, grades, and educational attainment, are significantly influenced by genetics (e.g., Ayorech et al. 2017; Branigan/McCallum/Freese 2013; Johnson/McGue/Iacono 2005; de Zeeuw/de Geus/Boomsma 2015). IQ research in particular has a long tradition in behavioral genetics, and previous studies show that heritability of adults' cognitive skills (i.e., IQ) is between 0.6 and 0.8 (Tucker-Drob/Briley/Harden 2013). Thus, genetic influences account for about 60 percent to 80 percent of total variation in IQ. This does not mean that environmental (i.e., social) influences are unimportant, because genetic tendencies are realized under social conditions (i.e., the proximate family environment) (e.g., Bronfenbrenner/Ceci 1994).

Moreover, environments that humans encounter are not random but are a function of an individual's genotype, referred to as "gene-environment correlations" (Plomin/DeFries/Loehlin 1977; Rutter 2007). Passive gene-environment correlations describe situations in which individuals are selected into environments that match their talents. For example, parents who favor classical music not only transmit such preferences, they also expose their children more often to this type of music. Thus, children inherit genetic dispositions but are also exposed to environmental influences in line with these dispositions. Evocative gene-environment correlations describe individuals' reactions to the genetic endowments of others; for example, gifted children might receive special treatment from teachers. Recent evidence shows that children's genetic make-up also influences how parents treat their children; for example, extrovert children might be treated differently from introvert children. Children's genetic make-up can therefore influence how parents react to them (Avinun/Knafo 2014; Klahr/Burt 2014). Finally, individuals actively search for environments that match their innate talent (niche picking), which is referred to as active gene-environment correlation.

If we do not take genetic heterogeneity into account, findings concerning the link between similarity and parents' social background (i.e., social transmission mechanisms) remain misleading. Genes affect cognitive ability directly, but they also operate indirectly in that genes influence how parents react to their children and/or how children react to their parents' investments. Thus, any similarity or dissimilarity of siblings might be driven by differences in genetic make-up.

2.3 Sibling, DZ twin, and MZ twin similarity

As noted, sibling similarity (i.e., sibling correlation) serves as an indirect test for parents' investment strategies. Sibling similarity can be understood as a summative measure for all measured and unmeasured influences of family background ("total family effect") (e.g., Sieben/Huinink/De Graaf 2001). The idea is straightforward: Because siblings are born and raised in the same family, everything that makes them alike can be attributed to shared family influences. The more alike siblings are, the stronger the influence of shared family influences. Conversely, differences among siblings emerge as a result of influences that are not shared by siblings and thus are specific to the child.

On an interpretive level, it is important to note that a low sibling correlation does not necessarily imply that family background is not important, because differences among siblings may be rooted in parents' actions (e.g., Björklund/Jäntti 2012; Conley 2008). In line with the theoretical assumptions outlined above, parents' efforts may lead to either sibling similarity or sibling dissimilarity. If parents compensate for differences, sibling similarity increases and shared family influences increase (H1). For efficiency reasons, there is still only one child who benefits from the parents' resources, but, as differences increase, shared family influences decrease. And even if parents allocate their resources equally (H2), shared family influences decrease to the extent that initial differences are reinforced. Thus, differences among siblings – lower sibling correlations – may be triggered by parents efforts. Given that non-shared or child-specific influences may be the result of parents' selective resource allocation, the interpretation of the similarity of siblings as the "total family impact" can be misleading (Conley 2008). Nevertheless, sibling correlations, as a descriptive measure, provide an understanding of whether stratification mechanisms on the societal level influence intra-family dynamics that lead to differences among siblings (ibid.).

On a conceptual level, it is important to note that sibling similarity summarizes not only the influence of parents' characteristics and associated resources, but also the impact of influences associated with the broader family context (i.e., neighborhood influences), genetic endowments, and effects that siblings have on one another (e.g., Conley/Glauber 2008). In the following, I explain why twins provide a better unit of analysis to capture shared family influences and how twins enable us to test whether a change in the similarity is associated with varying resources of the parents.

(Full) siblings are born and raised at different points in time and share about half of their DNA. Twins, by contrast, are born and raised at the same time, while MZ twins are, at conception, genetically alike (see Table 1).

Table 1: Similarity and dissimilarity of siblings and twins

	(Full) siblings	DZ	MZ
Exposure to <i>same</i> family conditions	No	Yes	Yes
Genetic overlap	~ 50 %	~ 50 %	~ 100 %
Sources of dissimilarity	Non-shared influences and genes	Non-shared influences and genes	Non-shared influences

It is common in stratification research to study the similarity of (full) siblings. Siblings may grow up under different family conditions (i.e., families might relocate, parents might switch jobs and/or re-partner) and differ in their genes. Thus, their similarity might result from either of these influences or from a combination of the two. Consequently, a change in the similarity might not be a direct consequence of varying parental resources and the associated investments. DZ twins are raised simultaneously, and hence they grow up under almost the same family conditions. For example, when twins grow up, their parents have the same occupational and educational status, and the twins live in the same neighborhood and probably attend the same school (or at least a school that is nearby). It is less likely that differences in the strength of the similarity between DZ twins can be attributed to the broader family context (because most of the contextual influences are shared). DZ twins are raised under most similar family conditions, while the rearing environment of (full) siblings can be very different. Thus, a change in the strength of similarity of DZ twins is more likely to be associated with systematic differences in parents' resources. Nonetheless, differences between DZ twins might still be due to their genetic differences. MZ twins are genetically identical and thus provide the most comprehensive measure for shared family influences because of their common upbringing and shared genes. Any difference among MZ twins must be the result of unshared influences – net of genetic factors. Studying MZ twins, therefore, makes it possible to rigorously test whether the similarity is associated with parents' social position and related investments.

Given the above, I argue that studying MZ twins provides the most rigorous test for the two hypotheses proposed earlier. The findings concerning the link between sibling similarity and parents' social background based on (full) siblings serve as baseline findings, because this is the general approach in stratification research. Results for DZ and MZ twins show to what extent the similarity changes when children are raised under the most similar family conditions (DZ twins) and if genetic heterogeneity is also controlled for (MZ twins).

Nonetheless, similarity between twins may also be the result of sibling effects – that is, of the influence siblings have on one another. This is a general concern when studying siblings and possibly even more so when studying twins. Previous studies have found that siblings have an effect on cognitive development (Azmitia/Hesser 1993; Brody 2004; Dunn 1983). Siblings may serve as teachers, which is beneficial to both the one being taught and the one teaching, because the teaching sibling has to reconsider a given subject, reduce the level of complexity, and find appropriate and/or easier explanations. Siblings are even more effective teachers than are peers, which may possibly be explained by their greater familiarity with and knowledge of their siblings' unique talents and weaknesses (Azmitia/Hesser 1993). Studies in this field analyze siblings. And it might be argued that interactions are not directly transferable to twins, who might have more similar knowledge than siblings who differ in age. However, as Dunn (1983) noted, sibling relationships are characterized by both “reciprocity” and “complementarity,” with the latter being positively associated with sociocognitive development. Reciprocal interactions, however, are very likely among twins, who share even more time with each other and know each other probably even better than (full) siblings know one another. I therefore argue that such learning processes are also prevalent in twin dyads.

Importantly, mutual influences among siblings might differ in how parents allocate their resources. When resources are scarce, sibling rivalry might be increased, which in

turn lowers mutual influences among siblings as they struggle for scarce resources. As competitors, it is unlikely that they will teach each other. However, siblings might also interact less with each other if there are plenty of resources, because they seek to set themselves apart to maintain their niche in the family system. Given that there is no empirical research on a possible stratification on siblings' relationships and their influence on cognitive outcomes, both scenarios are equally plausible. To rule out the possibility that sibling effects are not the main driver of sibling and twin similarity, I provide a sensitivity analysis that controls for the closeness of the twin and sibling relationships.

3. Data and methods

The analyses draw on newly collected data from the TwinLife panel study, a population register-based study of twins and their families residing in Germany (Diewald et al. 2017). These data make it possible – for the first time for Germany – to examine sibling and twin similarity in cognitive ability. Data collection started in 2014. TwinLife applies an extended twin family design in which the twins, their biological and social parents, and one sibling (if available) are surveyed. The information on zygosity (i.e., whether a twin is mono- or dizygotic) was obtained by means of physical similarity reports (self-reports or parents' reports) (see Lenau/Hahn 2017).¹ Due to the probability-based sampling strategy, TwinLife provides a unique opportunity to examine correlations in cognitive ability on a broad range of the social spectrum (Lang/Kottwitz 2017).

The analyses are based on young adult siblings and twins from the two oldest birth cohorts, aged between 17 and 25 years (birth cohorts 1997/98 and 1990-93, respectively). I excluded younger birth cohorts from the analysis (twins aged between 5 and 12), because age is a strong moderator of cognitive development (e.g., Cunha/Heckman 2007; Haworth et al. 2010), and the question how parents' social background affects cognitive ability at different stages of children's life course represents a study in its own right. Studying young adults is particularly interesting, because I can examine whether social background and associated allocation decisions have a lasting influence on cognitive ability.

To investigate sibling and twin similarity, I generated three samples: a sibling sample, a DZ twin sample, and an MZ twin sample. TwinLife samples twin families only (with or without additional non-twin siblings). Thus, siblings in the sibling sample are (full) siblings of twins who are randomly paired with one twin from the monozygotic or dizygotic twin pair (i.e., non-twin sibling-twin dyads). I restrict the minimum age of the siblings to the minimum age of twins (17 years) and the age difference to up to 8 years (i.e., two standard deviations from the age difference) in order to avoid the level of cognitive ability being affected by developmental differences within the sibling-twin dyad. Given the design of the TwinLife study, the sibling sample includes families with at least three children (i.e., the twin pair and one non-twin sibling), which is not necessarily the case for the twin samples considering that twins do not necessarily have a non-twin sibling. To ensure

1 The algorithm to determine the zygosity of twins was additionally cross-validated through genotyping procedures with a subsample of about 300 twin pairs (Lenau/Hahn 2017).

the results will not be influenced by fewer resources among families who have more than two children, I restrict the analyses to families with at least 3 and no more than 8 children (the maximum number of children in all three samples). The sibling sample comprises 726 siblings, the DZ sample 1,148 twins, and the MZ sample 1,232 twins.

3.1 Variables

The outcome of interest is that for cognitive ability. Cognitive ability is measured using the Culture Fair Intelligence Test (CFT 20-R), which is a standard psychometric test to measure nonverbal (fluid) intelligence (Weiß 2006). Individuals' cognitive ability scores are estimated using structural equation modeling. As recommend by the TwinLife group, I used age-corrected CFT scores (Gottschling 2017). I deleted observations with missing values for the cognitive testing (14% of the sample). Information on cognitive ability was missing more often among low-educated families ($p < 0.05$). Because lower-educated families are to some extent underrepresented, the findings concerning sibling and twin similarity tend to represent lower-bound estimates.

I use parents' education as an indicator of social background – that is, the highest level of education achieved by the parents (dominance principle).² I chose parents' education because it covers not only transmission mechanisms that run through economic resources but also resources that can be summarized as “cultural capital” that fosters children's cognitive ability. For example, more educated parents provide a stimulating home environment and activities, and they transmit distinct preferences and practices, all of which are linked to children's educational achievements (e.g., Cunha/Heckman 2007; Duncan et al. 1998; Lareau/Weininger 2003). Based on the CASMIN classification scheme (see Appendix 1), I distinguish low-educated (CASMIN 1a-c, 2b), medium-educated (CASMIN 2a, c), and highly educated parents (CASMIN 3a, b). CASMIN 2b refers to individuals with intermediate levels of general education but without vocational training. They are included in the lowest educational category for two reasons. First, the German labor market is highly credentialized and it is very uncommon to enter the labor market without any vocational training (e.g., Allmendinger 1989; Solga 2005). Second, due to educational expansion, the proportion of individuals with low levels of secondary education is decreasing, while the proportion of individuals with intermediate levels of secondary education is increasing (Solga 2005).³

CASMIN information was missing for 7.8% of the mothers and 32% of the fathers. I used multiple imputation with chained equations with 20 data sets for each observation to impute the missing information on education (van Buuren et al. 2006). The main variables for the imputation model are at the family level (i.e., they come from the twins' parents).

In sensitivity analyses, I investigate the role of mutual influences among siblings and twins. To indicate the closeness of a relationship, three questions were asked: *How often do you talk about important things with [name of the other sibling]? How often do you attempt to cheer up [name of the other sibling]?*, and *How close do you feel to [name of the*

2 The results do not change substantially if mother's education is used to indicate educational background instead (see Appendix A3).

3 The results remain stable if individuals with CASMIN 2b are in the group with medium education.

other sibling]?⁴ The response categories were never, rarely, occasionally, often, and very often. I used confirmatory factor analysis based on structural equation modeling to create an index of closeness (the coefficient of determination is 0.8). Table 2 shows the descriptive statistics for the sibling, DZ, and MZ samples.

Table 2: Descriptive statistics

	Siblings				DZ				MZ			
	Mean/ SD	Min.	Max.	N	Mean/ SD	Min.	Max.	N	Mean/ SD	Min.	Max.	N
<i>Individual (twin) level variables:</i>												
Cognitive ability	98.96 (16.49)	56	143	726	98.21 (16.49)	55	143	1148	99.30 (15.83)	55	146	1232
Age	20.73 (3.20)	17	31	726	19.82 (3.00)	17	25	1148	20.13 (3.02)	17	25	1232
Male	0.45 (0.50)	0	1	726	0.41 (0.49)	0	1	1148	0.42 (0.49)	0	1	1232
Closeness ^{a)}	0 (1.00)	-2.70	1.69	726	-0.23 (1.02)	-3.71	1.03	1148	0.22 (0.93)	-3.71	1.03	1232
Family size	3.56 (0.90)	3	8	726	3.54 (0.91)	3	8	1148	3.59 (0.90)	3	8	1232
<i>Family-level variables:</i>												
Parents' CASMIN (imputed)												
Low	0.18 (0.39)	0	1	726	0.18 (0.38)	0	1	1148	0.19 (0.39)	0	1	1232
Medium	0.47 (0.50)	0	1	726	0.47 (0.50)	0	1	1148	0.46 (0.50)	0	1	1232
High	0.35 (0.48)	0	1	726	0.35 (0.48)	0	1	1148	0.35 (0.48)	0	1	1232
Parents' CASMIN (unimputed)												
Low	0.20 (0.40)	0	1	712	0.18 (0.39)	0	1	1120	0.22 (0.41)	0	1	1198
Medium	0.46 (0.50)	0	1	712	0.47 (0.50)	0	1	1120	0.44 (0.50)	0	1	1198
High	0.34 (0.47)	0	1	712	0.35 (0.48)	0	1	1120	0.34 (0.47)	0	1	1198

Source: TwinLife Wave 1; own calculations. Standard errors in parentheses. ^{a)} Closeness is mean-centered.

The distribution of the main variable is fairly similar across all three samples. However, with regard to the closeness of the sibling and twin relationship, there are substantial differences: MZ twins are closest, followed by siblings and then by DZ twins. Differences between DZ and MZ twins have previously been found in the literature and might be explained by their closer resemblance in terms of both the rearing environment and their genetic make-up (Fortuna/Goldner/Knafo 2010). The fact that siblings are closer to one another than DZ twins are to each other is contrary to previous findings (which, however, were reported in studies based on small samples) and therefore requires more empirical investigation (*ibid.*).

4 Twins were asked the same questions.

3.2 Analytical strategy

To examine the similarity among siblings and twins, I use multilevel modeling in which siblings (level 1) are nested in families (level 2) (e.g., Raudenbush/Bryk 2002). Multilevel models (also known as variance decomposition models) are well suited for the question under study because they make it possible to separate out the different sources of variation in children's cognitive ability that is, shared family and non-shared child-specific influences. Given that the variance components are of particular interest, I separately specify empty models for each sibling sample. Based on this regression set-up, the intra-class correlation coefficient ICC can be calculated.

$$ICC = \frac{\sigma_b^2}{\sigma_w^2 + \sigma_b^2}$$

The ICC is defined as the ratio of the variance due to between-family differences (shared family influences) (σ_b^2) relative to the total variance (i.e., variation that can be attributed to the family (σ_b^2) plus variation that can be attributed to the child (σ_w^2)). A low ICC indicates high within-family stratification: despite shared family influences, siblings' outcomes differ from each other. Vice versa, a high ICC indicates a greater importance of shared family influences.

I first estimate variance decompositions for each sample (siblings, DZ twins, MZ twins) separately. I then estimate these models for each sample, differentiated by parents' education. The test for a systematic variation according to parents' education is based on the z-value of the differences in the ICCs (Conley/Glauber 2008; Conley/Pfeiffer/Velez 2007; Kenny/Kashy/Cook 2006). It is common in the sibling correlation literature to consider only the ICC, which is a standardized measure of the importance of the between-family (random effect) variance, at the expense of the variance components in absolute terms. However, the ratio stays the same if both variance components change simultaneously. Thus, the relative importance of shared family influences may change even if the ICC does not. To better understand the ongoing processes, I also provide information about the variance components in absolute terms (Erola 2012).

I estimate two-level random intercepts models with the mixed command in Stata 14.2 using the restricted maximum-likelihood option.

4. Results

Table 3 shows the results for sibling and twin similarity in the unrestricted sample (column 1) and their variation according to parents' education (columns 2 to 4). Figure 1 visualizes the findings. Table 3 reports three estimates of empty multilevel models: 1) the variance components in absolute terms as an indication of the underlying structure of the variation (Variance [family] and Variance [child]); 2) the intra-class correlation (ICC), which specifies the relative importance of shared family influences; and 3) the mean level of cognitive ability (constant), which provides information about the direction of shared family influences.

Table 3: Sibling and twin similarity in cognitive ability according to parents' education

	Overall		Low		Parents' education Medium		High	
	β /var	z-value	β /var	z-value	β /var	z-value	β /var	z-value
Siblings								
Constant	98.95 (0.71)	139.09	90.77 (1.96)	46.36	98.63 (1.09)	90.22	102.91 (1.07)	95.88
Variance (family)	96.47		147.38		73.09		58.62	
Variance (child)	174.55		125.03		186.97		181.65	
ICC	0.36 (0.05)	7.76	0.54 (0.10)	5.6	0.28 (0.08)	3.72	0.24 (0.08)	2.87
N		726		122		324		280
<i>Differences in ICC</i>	<i>z-value</i>							
Medium vs. high	2.03							
High vs. low	0.35							
Low vs. medium	2.34							
DZ twins								
Constant	98.21 (0.58)	170.7	90.39 (1.63)	55.37	96.22 (0.90)	106.96	103.36 (0.90)	115.06
Variance (family)	108.13		112.15		91.54		71.79	
Variance (child)	163.72		181.09		159.57		161.73	
ICC	0.40 (0.04)	11.32	0.38 (0.09)	4.02	0.36 (0.06)	6.11	0.31 (0.07)	4.69
N		1148		176		510		462
<i>Differences in ICC</i>	<i>z-value</i>							
Medium vs. high	0.19							
High vs. low	0.54							
Low vs. medium	0.61							
MZ twins								
Constant	99.3 (0.58)	169.81	92.77 (1.51)	61.5	99.63 (0.94)	106.11	101.83 (0.92)	110.42
Variance (family)	170.72		175.53		169.17		146.35	
Variance (child)	79.87		66.67		80.83		84.65	
ICC	0.68 (0.02)	31.54	0.72 (0.05)	14.44	0.68 (0.04)	19.23	0.63 (0.04)	15.41
N		1232		212		536		484
<i>Differences in ICC</i>	<i>z-value</i>							
Medium vs. high	0.63							
High vs. low	0.88							
Low vs. medium	1.41							

Source: TwinLife Wave 1; own calculations. Standard errors in parentheses.

I start with the results for the unrestricted sample (Table 3, column 1). These are baseline results for the degree of within-family stratification by sibling type. The similarity of (full) siblings is 0.36 (see ICC). Thus, more than a third of the total variation in cognitive ability can be attributed to shared family influences; child-specific influences account for about two thirds of the total variation. On average, siblings share about 50 percent of their DNA. Thus, genetic influences are included in the shared family component (if they lead to sibling similarity) and also in child-specific influences (if they lead to differences) (see Table 1). Since (full) siblings differ in age and genetic make-up, their similarity is comparatively low. However, the similarity of DZ twins is only slightly higher (40%). As noted earlier, DZ twins are born and raised at the same time. The rearing environment for DZ

twins is therefore much more similar compared with the rearing environment for siblings. Nonetheless, the correlation – and hence the degree of within-family stratification – in cognitive ability for siblings and DZ twins is about the same (0.40 for DZ and 0.36 for siblings). Thus, even under the most similar family conditions DZ are differently affected by them. The similarity of MZ twins is considerably higher (0.68), which can be explained by shared rearing and shared genes. The fact that the similarity is considerably higher for MZ twins reflects the importance of genetic influences for cognitive ability (e.g., Ayorech et al. 2017). Any difference between MZ twins results from non-genetic non-shared influences (see Table 1). About 30 percent of the total variation in cognitive ability is associated with child-specific influences – net of children's genes.

Next, I evaluate how the overall similarity changes according to parents' education (Table 3, columns 2-4). The results show that the degree of similarity decreases in all three samples from less to highly educated parents. The decrease in the similarity is most pronounced in the sibling sample. In less educated families, sibling similarity is about 0.54. Thus, half of the total variation in cognitive ability can be attributed to shared family influences. In highly educated families, by contrast, siblings correlate at about 0.24. Thus, child-specific influences are more important in highly educated families. As indicated by the z-values, differences in the similarity between medium- and highly educated families are statistically significant (z -value = 2.03), as are differences between less and medium-educated families (z -value = 2.34). Also in absolute terms, shared family background influences decrease sharply, whereas child-specific influences increase in families from low to medium-educated families. Given that the cognitive ability scores are more different in more highly educated families than in less educated families, the results provide preliminary support for hypothesis H2.

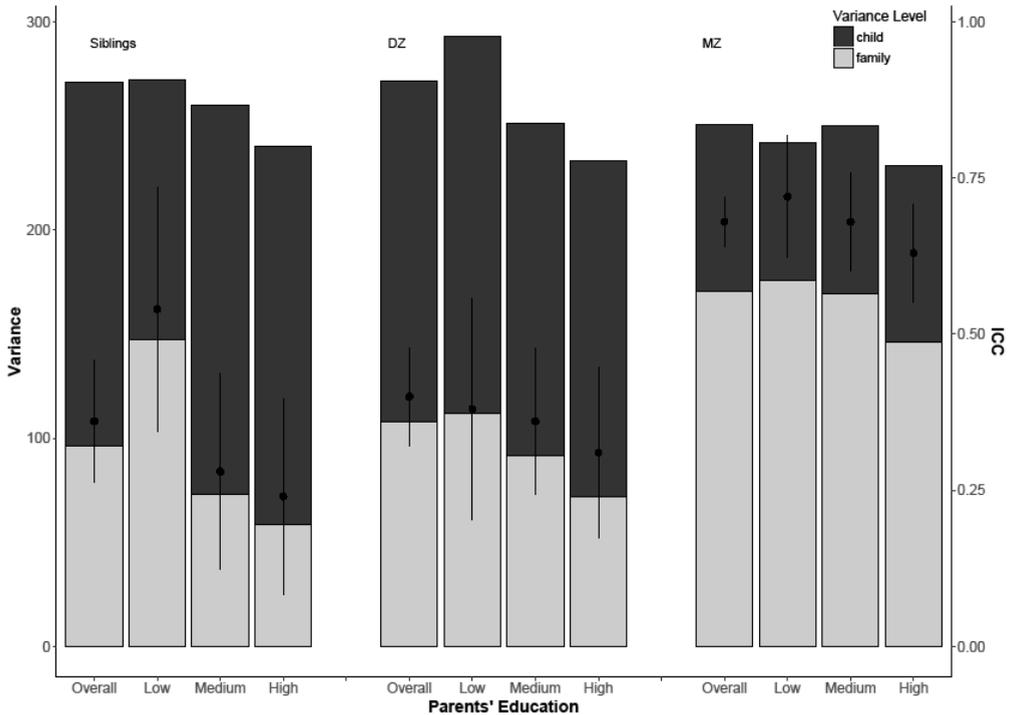
The similarity of DZ twins also decreases from less to highly educated families. In less educated families, the similarity of DZ twins is 0.38; in highly educated families it is 0.31. Although the decrease in the degree of similarity is not statistically significant, the results tend in the same direction, showing that the change in the degree of similarity is driven mainly by the decrease in the relative importance of shared family influences. This provides further indication that parents use their resources selectively once additional resources are available. Given that DZ twins and siblings differ only in the extent to which they are simultaneously exposed to the same family conditions, the significant decrease among siblings must be rooted in different family environments in which (full) siblings grow up.

Results for MZ twins reveal the same pattern. The similarity decreases from 0.72 in less educated families to 0.63 in highly educated families. The results for the variance components in absolute terms show the same trend: shared family influences decrease steadily from less to highly educated families, whereas child-specific influences – net of genes – become more important in the MZ sample. Thus, even for MZ twins, who are overall more similar than siblings and DZ twins because of their shared genetic make-up and shared rearing, differences are the more pronounced the more educated parents are.

Finally, I report the findings on the mean of cognitive ability (Table 3, Constant). For siblings, DZ twins, and MZ twins this mean level of cognitive ability increases with parents' education. The more resources parents have, the higher the mean value of cognitive ability. Since parents transmit 50% of their genes to their children the increase in the mean value of cognitive ability is also driven by direct genetic effects. To parcel out ge-

netic transmission, I would need the information on the correlation of children's and parents' genotypes, which I consider to be a study in its own right. However, parents' genes that are not transmitted also affect children's outcomes, since parents select environments based on their genetic makeup (indirect genetic effects) (Belsky et al. 2018). Previous research shows that environmental conditions created by more educated parents enhance genetic expression for cognitive skills such as IQ (i.e., they provide a rearing environment in which children can actualize their genetic potential (e.g., Guo/Stearns 2002; Turkheimer et al. 2003). Thus, parents pass down genetic influences that affect children's cognitive ability; however, whether children realize their genes and innate talent depends on the rearing environment their parents provide.

Figure 1: Sibling and twin similarity in cognitive ability according to parents' education



Interpreting the results for the mean values of cognitive ability along with the findings concerning the variance components, I find lower means for disadvantaged siblings and twins but a greater relative importance of shared family influences. This supports my expectation concerning family differences due to stratified parenting: Disadvantaged parents often lack the resources to make stimulating investments, which explains why disadvantaged children have, on average, lower levels of cognitive ability scores than do advantaged children. Given that investments of disadvantaged parents are more uniform and are intended to meet basic needs, siblings are also more alike in terms of cognitive ability (shared family influences are more important). Advantaged parents, by contrast, provide more child-specific inputs and address their children's need individually, which accentu-

ates differences in cognitive ability among siblings more strongly (shared family influences are less important). In all three samples, the relative importance of shared family influences is most pronounced in less educated families, which leads me to conclude that the same family influences that account for the similarity of siblings and twins in less educated families are also associated with lower levels of cognitive ability and are rather detrimental to the realization of cognitive ability. As discussed earlier, effects that siblings have on one another might lead to misleading results, particularly if sibling effects systematically differ according to parents' education. Sensitivity analyses have shown that the pattern identified exists over and above siblings' and twins' closeness (Appendix A2). The change in the similarity of siblings and twins cannot be attributed to systematic differences in the closeness of the sibling and twin relationship.

Taken together, the results show that in all three samples, shared family influences are more important in less educated families. The more education parents have, the less alike the cognitive ability scores of siblings, DZ twins, and MZ twins. This contradicts the expectation that highly educated parents compensate for differences, whereas less educated parents reinforce differences for efficiency reasons (H1). Instead, the results support the expectation that parents make equal investments and but adopt different parenting concepts that accentuate differences among advantaged siblings (H2). Given that the analyses are based on a sample of young adults, the results show that shared family influences have a lasting impact on cognitive ability, which is stronger for less educated families. As the findings concerning the mean value of cognitive ability have shown, these influences are not necessarily conducive to the realization of cognitive ability – in fact, quite the opposite.

5. Discussion and conclusion

I studied sibling similarity in cognitive ability and asked whether the degree of similarity varies with parents' education. In contrast to previous research, I extended the established sibling correlation approach to DZ and MZ twins. This acknowledges the increasing evidence that genetic variation matters for cognitive ability and allows us to capture shared family influences more comprehensively, and thus to test rigorously the link between sibling similarity and parents' education.

To explain a varying degree of similarity, I first referred to economic approaches that model parents' investment decisions within the household (Becker/Tomes 1976; Behrman/Pollak/Taubman 1982). Against this backdrop, I tested the hypothesis that sibling similarity in disadvantaged families is lower for efficiency reasons, whereas highly educated families compensate for, and thus equalize, differences among siblings (Conley 2004, 2008). I then introduced the idea that parents might also invest equally in and accept differences among their children. I drew on the literature on stratified parenting (e.g., Cheadle/Amato 2011; Kalil/Ryan/Corey 2012; Lareau 2011; Lareau/Weininger 2003) and put it in a within-family perspective. Because advantaged parents adopt an active role in shaping the developmental processes of their children and tend to provide more skill-enhancing and specific inputs in line with children's potentials and needs, I hypothesized alternatively that siblings from advantaged families are less similar in terms of cognitive ability compared with siblings from disadvantaged families.

My analyses yielded two findings. First, young adult siblings, DZ twins, and MZ twins in highly educated families are less alike in terms of cognitive ability compared with young adult siblings, DZ twins, and MZ twins in less educated families. This contradicts the hypothesis concerning stratified investments rationales, according to which sibling similarity increases with parents' social background (H1), and supports the hypothesis concerning equal investments and stratified parenting (H2).

Systematic differences in the degree of similarity in cognitive ability are significant in the sibling sample. This is in line with US findings for literacy skills (Conley/Pfeiffer/Velez 2007) but differs from the finding for Germany (Grätz 2018). One explanation of the divergent findings could be that the families I studied have more children (twins and at least one sibling) than the families in the study by Grätz (2018). Unfortunately, this study does not provide information about the variance components in absolute terms. The ICC is a standardized measure that does not change if the variances of shared family and child-specific influences in absolute terms change at the same time. Thus, there might be some variation in the relative importance of shared family influences that did not show up in the ICC. To evaluate to what extent results differ substantially, we would also need information on the family level variation in absolute terms.

For both DZ twins and MZ twins, the results reveal the same pattern. The similarity decreases according to parents' education, though it is not statistically significant. Nonetheless, both the results for the variance components in absolute terms and for the ICC confirm that shared family influences decrease the more educated parents are. Thus, the more resources parents have, the more important are processes within the family that accentuate differences within the family.

In addition, I found that the mean level of cognitive ability increases with parents' education, whereas the relative importance of shared family influences decreases. These divergent trends show that the same shared family influences that make siblings and twins more alike are also associated with lower levels of cognitive ability. This is a very important aspect, and more research is needed to understand what kind of influences affect siblings equally and hamper the realization of cognitive ability in less educated families. In advantaged families, by contrast, parents often provide additional inputs that foster children's talents. These influences are more child specific, which leads to higher levels of cognitive ability and promotes differences in cognitive ability among their children. Given that differences between siblings and twins from advantaged and disadvantaged backgrounds remain even as the children grow older, my results indicate a long-lasting impact of parenting on cognitive ability.

Second, my results show that the association between parents' educational background and sibling and twin similarity is not affected by the closeness of the sibling and twin relationship. I thereby address a major limitation of studies on sibling similarity. In a similar vein, my results reveal a very similar trend for siblings, DZ twins, and MZ twins, which shows that there is no "twinning effect" – that is, that twins behave profoundly differently from (full) siblings.

However, it is important to note that I used an indicator that was measured at the same time as cognitive ability. Since the quality of the sibling and twin relationship might change over the life course, it is important to back up my results – ideally, with longitudinal data. To the extent that there are no profound changes in the sibling and twin relationship until early adulthood, my results are reliable.

This study is the first to adopt a genetically sensitive approach to sibling similarity in cognitive ability. The results provide strong indications for parent's investment decisions that are not in line with economic theories, rather parents invest equally in their children but in distinct ways that differ according to parents' educational background. My findings challenge the implicit assumption that shared family influences such as parents' education influence children in similar fashion. Moreover, if children are raised in advantaged families, shared family influences – those that differ between families – are less important. Genetically sensitive research can help us to better understand what kinds of parental investment – net of genetic influences – result in within-family stratification, and to formulate informative policy suggestions to enhance the achievements of children from less educated families.

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Appendix

Table A1: CASMIN educational classification

1a	inadequately completed
1b	general elementary education
1c	basic vocational qualification
2a	intermediate vocational qualification
2b	intermediate general qualification
2c_gen	general maturity certificate
2c_voc	vocational maturity certificate
3a	lower tertiary education
3b	higher tertiary education

Table A2: Sibling and twin similarity in cognitive ability according to parents' education (controlled for siblings and twins closeness).

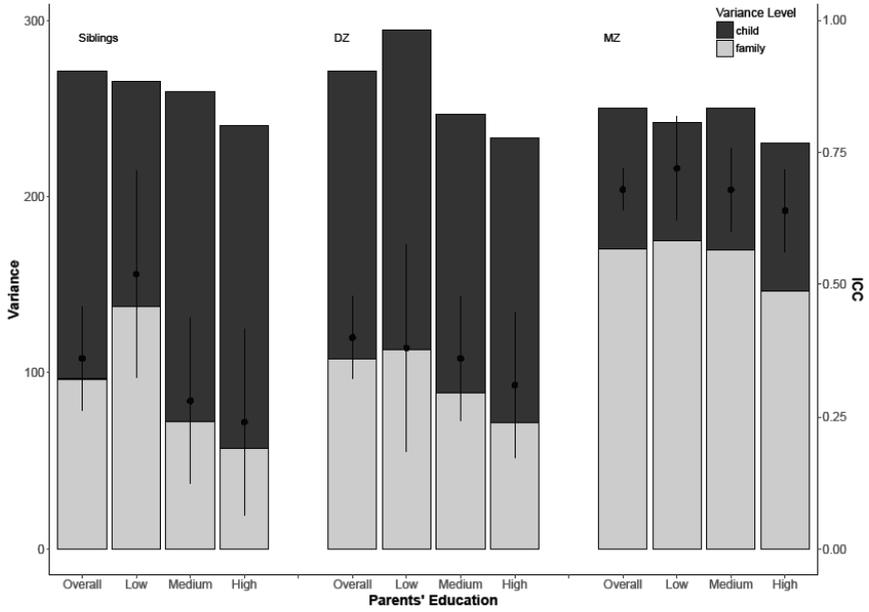


Table A3: Sibling and twin similarity in cognitive ability according to mothers' education.

