Pathways of intergenerational transmission of advantages during adolescence

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Pathways of Intergenerational Transmission of Advantages during Adolescence: Social Background, Cognitive Ability, and Educational Attainment

Abstract

Educational attainment in adolescence is of paramount importance for attaining higher education and for shaping subsequent life chances. Sociological accounts focus on the role of differences in socioeconomic resources in intergenerational reproduction of educational inequalities. These often disregard the intergenerational transmission of cognitive ability and the importance of children's cognitive ability to educational attainment. Psychological perspectives stress the importance of cognitive ability for educational attainment but might underemphasize potentially different roles of specific socioeconomic resources in shaping educational outcomes, as well as individual differences in cognitive ability. By integrating two strands of research, a clearer picture of the pathways linking the family of origin, cognitive ability, and early educational outcomes can be reached. Using the population-based TwinLife study in Germany, we investigated multidimensional pathways linking parental socioeconomic position to their children's cognitive ability and academic track attendance in the secondary school. The sample included twins (N = 4008), respectively ages 11 and 17, and siblings (N = 801). We observed strong genetic influences on cognitive ability, whereas shared environmental influences were much more important for academic tracking. In multilevel analyses, separate dimensions of socioeconomic resources influenced child cognitive ability, controlling parental cognitive ability. Controlling adolescent cognitive ability and parental cognitive ability, parental socioeconomic resources also directly affected track attendance. This indicated that it is crucial to investigate the intertwined influences on educational outcomes in adolescence of both cognitive ability and the characteristics of the family of origin.

Keywords: educational attainment; academic tracking; parental education; parents' occupational status; parental income; cognitive ability, genetic and environmental influences

Introduction

The role of the family of origin in influencing children's life chances is a topic studied across various disciplines. Since intergenerational transmission of advantage is, at the observed level, to a large extent mediated by education (Blau and Duncan 1967; Breen and Jonsson 2005), its role in status attainment processes has been extensively studied. Adolescence is a critical period which shapes educational attainment and thus subsequent life chances. This is particularly true in stratified education systems such as Germany's, where adolescents are streamed into different school tracks that determine access to higher education (Van de Werfhorst and Mijs 2010). Moreover, tracking influences learning opportunities and presents an important context for development in early adolescence (Steinberg and Morris 2001). In this life phase, individual characteristics and activities become increasingly important compared to parental influences during childhood (Beyers et al. 2003). However, with regard to educational inequalities, much research has demonstrated a long shadow of the family of origin. It is therefore important to understand how characteristics of the family of origin and characteristics of adolescents bring about unequal chances to reach higher education. In this article we scrutinized the intertwined pathways among family of origin, cognitive ability, and educational attainment, measured by academic track attendance in Germany, i.e. whether or not a child attends a secondary school that leads to tertiary education.

Despite the paramount importance of track attendance, the mechanisms by which family-of-origin resources influence this transition are not well understood. Moreover, established associations between the family of origin and adolescent educational attainment prompt surprisingly divergent interpretations among researchers in different disciplines. Most of the sociological literature explains educational outcomes through differences in availability of financial, cultural, and social resources. Each of these resource dimensions links family of origin with educational attainment through distinct mechanisms (Bourdieu 1986). However, parental cognitive ability affect each form of resource, and parents influence children's cognitive abilities both genetically and through the resources they offer. This means that resources may only be mediators of underlying parental abilities, and this is rarely discussed, and much less investigated, within sociology. Economists and sociologists often assume that individual differences in cognitive ability are exogenous to family-of-origin influences (Bukodi et al. 2014; Korenman and Winship 1995) and often use no or rather crude measures of cognitive ability (Strenze 2007).

In contrast, in the psychological literature a venerable line of research focuses on explaining individual differences in cognitive ability (Deary 2012), and its influences on life outcomes, and demonstrates the paramount impact of cognitive ability vis-à-vis other individual characteristics, such as personality traits, in influencing educational outcomes (e.g., von Stumm et al. 2009). That parental resources foster individual development and educational attainment is acknowledged but most often in terms of general accounts that resource-rich environments are beneficial for cognitive development. In psychological research, different indicators of social origin are often lumped together, sometimes relying on crude proxies of dimensions of socioeconomic resources, such as the number of rooms in the home and car ownership (Bradley and Corwyn 2002; White 1982), while sociological research has demonstrated that mechanisms associated with different resource dimensions are not interchangeable (Hauser and Warren 1997).

Taken together, evidence points to intertwined pathways impacting educational attainment and the development of cognitive ability. More specifically, parental cognitive ability is related both to the financial, cultural, and social resources of the parents themselves and to children's cognitive ability (Björklund 2010; Black et al. 2008), and parents use both their own cognitive ability and these resources to impact children's cognitive ability and educational attainment (Bradley and Corwyn 2002; Duncan and Magnuson 2012). In turn, children's cognitive ability is an important predictor of educational attainment (Strenze 2007), and intergenerational genetic transmission and gene-environment correlation are involved throughout, though to varying degrees (Freese and Jao 2015). The implications of genetic involvement call into question the standard sociological conception of family resources as exerting homogenous influences, which similarly impact all offspring. This is because, at least in adulthood, cognitive ability tends to show effectively no shared environmental influences. Educational attainment shows moderate shared environmental influence, but they generally account for less than half the variance (Freese and Jao 2015).

In this article, we attempted to integrate contributions from the different perspectives and the, so far, largely independently evolving fields. We do so by analyzing links between the family of origin – parental socioeconomic resources and cognitive ability – and how these shaped children's cognitive ability and educational attainment as measured by academic track attendance in Germany.

Germany's education system is strongly stratified and hierarchically organized, especially in comparison with the US or Great Britain (Allmendinger 1989; Kerckhoff 2001). In such stratified systems, academic tracking functions as a launching pad for subsequent educational trajectories. After elementary school, at around age ten, students attend separate lower, intermediate, or upper – academic – secondary tracks. The lower- and intermediate-level tracks are vocationally oriented while attaining the *Abitur* at the end of the academic *Gymnasium* opens the way to university education. Pupils are streamed into tracks based on teachers' recommendations during fourth grade. These recommendations are supposed to be guided by educational performance, but parental influence also plays a strong role (Roth and Siegert 2016).

The education system has seen reforms in recent years, with increasing numbers of integrated schools (in German "Gesamtschule"), which either integrate the lower two tracks or offer all three tracks within a single school. However, the overall system remains strongly stratified, with the three separate-track schools still being predominant, and integration of just the lower and middle tracks being more common than the inclusion of the higher track. Stratification based on family social background is relatively strong after the secondary transition at age ten (Stocké 2007) and is visible after that, especially again at transitions into tertiary education (Reimer and Pollak 2010). Therefore, Germany offers an intriguing opportunity for comparing antecedents of educational attainment and cognitive ability, since early tracking is quite decisive, though not irreversible (Hillmert and Jacob 2010).

We based our analyses on the newly available TwinLife data of 4,000 twin families in Germany. TwinLife comprises four birth cohorts assessed in 2015-16 – we focused on adolescents aged about 11 and 17. TwinLife includes reliable, standardized, and multidimensional measures of sociological as well as psychological constructs relevant to social inequality research, including the Culture Fair Intelligence Test (CFT 20-R), a widely used and validated cognitive test battery that assesses non-verbal intelligence (Catell and Catell 1960, Weiss 2006).

We first provided a descriptive account of how variance in cognitive ability and educational attainment can be attributed to environmental and genetic influences based on variance decomposition. With some assumptions, such decomposition in twin samples can distinguish among genetic, shared, and non-shared environmental influences. This served as a basis for investigating pathways of socioeconomic resources and cognitive ability in shaping educational attainment in adolescence. We analyzed the multidimensional pathways linking parental socioeconomic position to children's cognitive ability and track attendance. We considered distinct socioeconomic resources that are each related to cognitive ability and educational outcomes in particular ways. In a next step, controlling parental cognitive ability, we addressed to what extent socioeconomic resources influenced child cognitive ability. Furthermore, by controlling parental cognitive ability in the association between child cognitive ability and academic track attendance, we addressed to what extent parental socioeconomic resources exerted direct effects on track attendance.

Parental Socioeconomic Resources and Children's Outcomes

Socioeconomic status refers to access to economic and social resources and the social positioning, privileges, and prestige that derive from these resources. In the following, we discuss the primary components of parental socioeconomic resources: education, occupational status, and income. The underlying contributing mechanisms and relative importance of these various socioeconomic resources, however, may be quite different, depending on the outcomes in question and on the larger societal context such as the type of welfare state (Beller and Hout 2006; Korpi 2000; Sørensen 2006). Accordingly, we discuss the specific pathways by which these resources are related to cognitive ability and educational attainment separately. However, it is important to note that none of these studies included controls for parental cognitive ability, nor were they specifically designed to address the intergenerational transmission of genes for cognitive ability.

Parental socioeconomic resources and child cognitive ability. ***Parental education*****.** Evidence of the association of parental education with children's cognitive ability is robust (Nisbett et al. 2012). Sociological theories suggest that parental education reflects orientations about the value of social mobility and desirable outcomes in children that in turn motivate certain parental behaviors (Sewell, Haller, and Ohlendorf 1970). The suggested main environmental mechanisms are the quantity and quality of child-parent interactions. One pathway linking educational attainment to child cognitive ability is quantifiable differences in the quantity and quality of language exposure for children of parents with professional jobs in comparison with children from working-class families. For example in families with higher educational qualifications, children heard 30% more words by the age of three, and a larger variety of vocabulary (Hart and Risley 1992). Mothers with higher levels of education were found to spend more time with their children, irrespective of time and resource constraints (Kalil et al. 2011; Sayer et al. 2004). Studies have also observed that parental education is associated with cognitively stimulating parenting activities and children's language development, including sentence structure and vocabulary use, involvement in decision-making, and use of symbolic references (Harding et al. 2015; Hart and Risley 1992). These associations between parental education and cognitive outcomes remained when family income was controlled (Mercy and Steelman 1982). And research specifically in Germany suggested that parental education was directly related to adolescents' cognitive ability (cf. Karbach et al. 2013).

Parental occupational status**.** Theoretically, type and status of employment can also be linked to parental incentives to invest in their children's' cognitive development. Qualitative accounts suggest that parental experiences in the occupational sphere shape their child-rearing goals and behaviors (Lareau 2011; Pearlin and Kohn 1966). Other studies have also observed that parents in higher status jobs choose organized activities that provide their children and adolescents with stimuli for their cognitive development (Bodovski and Farkas 2008; Farkas 2003). A limited number of studies has focused explicitly on the link between occupational status and children's cognitive attainment. For example, Parcel and Menaghan

(1990) observed that parents with occupations with higher levels of task variety and problem solving provided more stimulating environments, which were associated with children's cognitive abilities.

***Parental income*.** According to economic models, parents with greater economic resources can make more financial investments that stimulate children's cognitive ability (Becker and Tomes, 1986; Haveman and Wolfe, 1995). The role of income in children's cognitive ability has been addressed largely by focusing on their lack, i.e. poverty. The disadvantages faced by children from families that lack financial resources have been extensively documented (Brooks-Gunn and Duncan 1997). Mechanisms that link parental financial resources and child cognitive ability include materials in the home; opportunities to engage in and learn sports, musical instruments, dance, drawing, languages, etc.; culturally broadening experiences such as travel; and quality health care (Duncan et al. 1998; Guo and Harris 2011). The majority of studies on the relations between income and child cognitive ability come from the US. In contrast, in Germany, a country with a more extensive welfare state, the few studies on this topic have usually indicated rather weak associations between income and cognitive development, and associations have been restricted to the lowest income levels (Biedinger 2011). Effects of lower income levels tend to be greater in the US as well, suggesting that income is most important when it creates actual poverty.

Parental socioeconomic resources and child educational outcomes. *Parental education*. Arguably the most important resource in fostering child educational attainment is parental education. According to the classical status attainment model, parents who have had higher education tend to be better able to support their children's performance at school and to maneuver them through the education system (Blau and Duncan 1967; Sewell et al. 1970). This line of research suggests that parental education is associated with orientations, strategic knowledge of the workings of the education system, and, not least, personal experience of the value of education and skill development (De Graaf and Ganzeboom 1993). In stratified education systems, where decisions on educational tracking take place early, institutional knowledge about educational track assignments can be expected to be especially important. Indeed, the importance of parental education seems to trump that of economic resources: children from families with low income but higher education were found to be more likely to take the academic track than children from families with high income but lower educational qualifications (Schneider 2004).

***Parental occupational status*.** According to the Breen-Goldthorpe model (1997) of educational attainment, parental motives to maintain the social status of the family is an important influence on educational decisions. According to this model, higher status families have higher motivations to invest in educational careers that lead to higher degrees. For Germany, Stocké (2007) observed that parental motives to avoid downward mobility influenced their educational track decision for their children. Parental occupational status also quantifies sociocultural resources related to one's job. Bourdieu's (1984) concepts of different forms of capital includes cultural capital, that describes modes of conduct and use of language, one's "habitus", including values and motivations, and aspirations are related to one's job. Cultural practices, including participation in "high-status" cultural activities, are suggested to work as mediating factors that relate parental occupational status to the educational outcomes of children (De Graaf 1988; Sullivan 2001). Higher-status children may therefore be advantaged in comparison with their counterparts with lower-status background because they are familiar with the so-called dominant culture and they more easily accept the schooling system as the legitimate way to reach their educational and occupational goals. Research found for example that the activities and aspirations associated with their parents' occupational status were rewarded in the education system (Jaeger 2011).

Parental income. From economic models it also follows that families differ with regard to the disposable resources they can invest in the educational success of their children (Becker and Tomes, 1986; Haveman and Wolfe, 1995). Parental income captures economic resources that allow parents to invest in their children's educational performance (Brooks-Gunn and Duncan 1997; Haveman and Wolfe 1995). The largest body of research linking parental income to educational outcomes stems from the US, suggesting that income is related to children's chances to achieve higher levels of attainment, but generally rather weakly. Income was found to enable families to purchase materials, experiences, and services to foster their children's educational performance. For example, more affluent families invested in child care, food, housing, learning materials and opportunities, and avoidance of household stressors (Duncan et al. 2011; Guo and Harris 2011; Yeung et al. 2002). As noted earlier, in Germany, income plays a smaller role in educational attainment (De Graaf 1988; Stocké 2007). Opportunity costs for pursuing higher education are smaller; moreover, studies observed that the value of and preference for educational attainment are more decisive for children's educational careers (Schneider 2008). A small number of German studies have assessed the relationship between income and tracking, focusing on the lowest end of the income distribution. These found that longer periods of poverty during early childhood were associated with children's educational attainment (Gebel 2011; Schöb 2001).

Parental socioeconomic resources and parental cognitive ability. It remains unclear to what extent associations between parental resources and children's cognitive ability and educational attainment might be overstated when parental resources are products of unmeasured parental ability. Parental cognitive ability jointly influences the socioeconomic resources they can offer their children and the children's cognitive ability as well as their educational attainment – both genetically and environmentally. Parents with higher cognitive ability are more likely to have attained higher levels of education, more success in the occupational sphere and, consequently, a higher income (Deary et al. 2007) (Strenze 2007). The few studies that have controlled parental cognitive ability when assessing the relations between parental resources and offspring outcomes have found much smaller associations between measures of parental education, occupation, and income, and children's cognitive ability (Blau 1999; Johnson and Nagoshi 1985; Mayer 1997). Likewise, Doren and Grodsky (2016) observed that parental cognitive ability largely accounted for the relation between parental income and offspring college attendance and completion.

Cognitive Ability and Academic Tracking

Adolescent cognitive ability and academic tracking. Previous studies have shown that adolescents' cognitive ability is an important predictor of educational achievement (Gustafsson and Undheim 1996; Strenze 2007). Research in Germany on the tracking decision suggests that children's cognitive ability is indirectly and directly associated with teachers' recommendation. Children with a higher cognitive ability were found to achieve higher grades, and these serve as a basis for teachers and parents in deciding on the most appropriate track. However, children's cognitive ability was also found to directly influence teachers when recommending the most appropriate school track, even when grades were accounted for (Ditton et al. 2005).

Environmental and genetic pathways. Parental cognitive ability thus confounds the relations between parental socioeconomic resources and children's cognitive ability and educational outcomes both genetically and environmentally because parents pass both their genes and their environmental resources to their children. Behavioral genetics can provide clues about the pathways through which this occurs. It can provide estimates of proportions of variance in characteristics attributable to (additive, individual genetic variants acting independently) genetic variance (A) and environmental variance – shared (or common) environmental variance (circumstances that act to make family members similar; C) and non-shared environmental variance (circumstances that act to make family members different; E). It does so by statistically leveraging the observable similarities in relatives with varying degrees of genetic relatedness (such as siblings, identical and fraternal twins). The E component also includes measurement error. Importantly, experiencing the same circumstances does not necessarily make family members similar, so not all shared circumstances can be considered sources of shared environmental variance. Analogously, different circumstances can make family members more similar, so not all different experiences can be considered sources of non-shared environmental variance. The estimated proportion attributable to genetic differences is often termed heritability. High heritabilities should not be misinterpreted as genetic determinism, as these estimates refer only to variance rather than level, and say nothing about the underlying mechanisms.

While single estimates of heritability are of limited relevance because the heritability of a trait is contingent on variations in both environmental context and sample population (Diewald et al. 2015; Freese 2008; Visscher et al. 2008), the overall pattern of heritability estimates of cognitive ability vis-à-vis educational outcomes presents intriguing insights. Many studies have shown that shared environmental influences on cognitive ability tend to be minimal after early childhood (Polderman et al. 2015). This is a challenge to sociological conceptions, in which parental resources are (most often implicitly) understood as a shared environmental influence (Freese 2008). Genetic influences on cognitive ability range from 0.4 to 0.8 and thus on average account for the largest proportion of cognitive ability variation. Low shared environmental influences, however, cannot be equated with the absence of such influences. In early childhood, cognitive ability shows greater shared environmental influences (Briley and Tucker-Drob 2013). According to the dominant explanation for this, shared environmental influences are obscured by the reinforcing interplay of environmental and genetic influences (Dickens and Flynn 2001; Deary et al. 2012; Flynn 2007; Trzaskowski et al. 2014). Nevertheless, at all ages genetic influences on cognitive ability are substantial. Genetic transmission of parental cognitive ability to child cognitive ability is thus an important pathway that confounds the relations between socioeconomic resources and child cognitive ability.

Educational attainment offers an interesting exception to the pattern of low shared environmental influences found for cognitive ability: variance decompositions of educational attainment show clear shared environmental influences. In an extensive meta-analysis, Branigan et al. (2013) observed that the average proportion of variance attributable to shared environmental influences was comparable to that attributable to genetic factors, and in one-third of cases even larger than the genetic component. It is hence more likely that socioeconomic resources influence measures of educational attainment in the form of homogenous influences as conceptualized in sociology. However, the variance decompositions clearly indicate that educational attainment is also subject to genetic influences, which are likely largely to follow from the heritability of cognitive ability (Nisbett et al. 2012). Studies in this area have assessed adult educational attainment, including tertiary education. Tertiary education is generally a crucial factor in this, and it is often strongly influenced by parental financial and cultural resources.

Current Study

In this study, we made use of the first wave of TwinLife, a population-based twin-family study in Germany, to investigate pathways of socioeconomic resources and cognitive ability in shaping inequality of educational attainment in adolescence. Since academic tracking in Germany is decided at an early age and presents a rather definitive decision point for tertiary education (Hillmert and Jacob 2010), we expect to find substantive environmental influences. Moreover, we expected each of the socioeconomic resources to present distinct dimensions that might benefit children's cognitive development and academic track attendance in different ways. Moreover, we expected that relations between socioeconomic resources and both children's cognitive ability and academic track attendance would be overstated if parental cognitive ability were not controlled for. This was particularly relevant for cognitive ability, where variance is mostly attributable to genetic variation. In the following analyses, we thus investigated how much of the variation in cognitive ability and academic tracking could be attributed to genetic and environmental influences and whether there were direct associations between parental resources and cognitive ability and between parental resources and tracking when parental cognitive ability was controlled.

Method

Sample

The sample for this study came from the first wave of TwinLife, a prospective longitudinal study of twins and their families in Germany (Diewald et al. 2016). The first assessment comprised four cohorts, each of approximately 500 pairs of monozygotic (MZ; identical) and 500 pairs of same-sex dizygotic (DZ; fraternal) twins, their parents, and one additional full sibling, if present. Sampling was based on administrative data from communal registration offices. Due to a stratified random sampling strategy based on administrative information, the sample was more representative of the full population than some twin studies that have relied on calls for volunteers (Lang and Kottwitz 2017). Basing analyses involving genetic influences on population-representative samples including families across the full range of social strata, including those at the lower and upper ends, is very important as the estimates are highly sample-sensitive (Johnson et al. 2009). The TwinLife study is particularly suited for the research question at hand, as it includes reliable, standardized, and multidimensional measures of sociological as well as of psychological constructs relevant for social inequality research. Of the four birth cohorts (C1: born 2009-2010, C2: born 2003-2004, C3: born 1997-1998, C4: born 1991-1992), we focused on C2 and C3, who were about 11 and 17 years old at the time of the first assessment (N = 4008), excluding twins with unclear zygosity (n = 7). In multivariate analyses, we additionally included siblings, who were at least ten years of age (N = 801), this being the minimum age to attend secondary education. The siblings were between 10 and 31 years of age. For 97% of the children in the sample a mother was present in the household, for 78% a father was present, and 75% lived with both parents. Missing values on other covariates were imputed using multivariate imputation by chained equations (White et al., 2011) creating 20 data sets (see Table 1 for sample descriptives and information on missing values and Table A2 in the appendix for correlations among the covariates in the multivariate models).[1]

Measures

Cognitive ability. Twin, sibling, and parental cognitive ability was assessed using the Culture Fair Intelligence Test (CFT 20-R), a widely used and validated cognitive test battery that assesses non-verbal intelligence (Catell and Catell 1960; Weiss 2006). The CFT was designed to minimize the influence of sociocultural and environmental characteristics such as verbal fluency and educational level. However it actually reflects these strongly, as evidenced by its large Flynn Effect. It comprises four subtests in figural reasoning (series), figural classification, matrices, and reasoning (topologies; see Gottschling, 2017) for details). The test implemented in the TwinLife survey had 15 items each for subsets of figural reasoning (series), figural classification, and matrices and eleven items for reasoning (topologies). The CFT's internal consistency in the TwinLife study was satisfactory (alpha = 0.80). It generally shows high test-retest reliability (Weiss 2006). Normalized CFT scores were generated using a factor analysis by predicting the factor scores (see Table A1 in the Appendix).

Academic track attendance. Academic tracking was measured using information on current secondary school attendance. Originally, respondents indicated what type of school they were attending at the time of the first assessment. From this information, we created a binary variable indicating being enrolled in an upper, or Gymnasium, secondary school (1) or not (0), excluding all children who were still attending primary school (including so-called orientation-level schools, which delay the tracking decision). If the information on current school type did not allow for an unambiguous classification of tracking, because the respondents were enrolled in a comprehensive secondary school (about 13%), which offers both upper and lower secondary tracks, this was coded as 0. Results were robust to coding these as 1 (see robustness check). Due to the age range, the vast majority of twins and siblings in the sample still attended school (88%). To avoid excluding respondents who had finished school, we used information on highest school degree for those did not attend school anymore.

Parental cognitive ability. Parental cognitive ability was operationalized as the mean CFT scores of the children's biological parents.

[1] In addition to the covariates used in the multivariate analyses, we also used information on the interviewers (age, sex, and tenure with the survey institute), information provided by the interviewer regarding the dwelling, household and family size and composition, region, and community size to generate the imputations.

Parental educational level. The family's educational level was operationalized as the higher of household-present mother's and father's educational attainment based on the 1997 version of the UNECSO's International Standard Classification of Education (ISCED). We used the collapsed version which comprises three categories, ISCED levels 1 and 2 (primary and lower secondary education), levels 3 and 4 (upper secondary and post-secondary non-tertiary education), and levels 5 and 6 (first and second stage of tertiary education). For a detailed description of the ISCED 1997 version see Schneider and Kogan (2008).

Parental occupational status. Parental occupational status was operationalized as the higher of mother's and father's status based on the International Socio-Economic Index of Occupational Status (ISEI, Ganzeboom et al. 1992). The ISEI is an established measure of occupational status, based on average educational levels and earnings in different occupations (Ganzeboom et al. 1992). It can range from 16 to 90. In order not to exclude households in which both parents were non-working (about 10%), we assigned zero if a parent was not working. This allowed us to include parents in the analysis who did not have a valid ISEI score because they did not work. This so-called dummy variable-method does not cause bias in estimation if a binary variable that indicates replacement is included in the analysis (Allison 2002: 9, 87).

Parental labor force participation. From information on current labor force participation, we created a binary variable indicating whether at least one parent was working (0 = both not working, 1 = at least one parent working). It served as a control indicating that the ISEI was replaced with zero for families in which both parents did not work.

Household financial resources. To capture the available financial resources in a household, we used the monthly net equivalent household income in Euros based on the new OECD scheme, which adjusts the reported net household income by household size (OECD 2013). We created income quantiles, which separates the income distribution into five shares of equal size.

Age and sex. In the multivariate analysis we controlled age (in years) and sex (0 = female, 1 = male).

– Table 1 about here –

Analysis Strategy

The analysis had two parts. First, using twin-only data, we decomposed the variance in cognitive ability and tracking into genetic and environmental influences components. Second, using twin and sibling data, we estimated associations between parental resources and cognitive ability and between family characteristics and tracking.

The variance decomposition estimated how much of the overall variation in a trait can be attributed to (additive) genetic (A), shared environmental (C), and non-shared environmental (E) influences by comparing resemblances between mono- and dizygotic twin pairs. Under this so-called ACE model, total observed (phenotypic) variance (σ_P^2) is assumed to be the sum of independent A, C, and E variance components[2]:

$$\sigma_P^2 = \sigma_A^2 + \sigma_C^2 + \sigma_E^2 \qquad (1)$$

The model relies on the facts that MZ twins are genetically 100% identical, while DZ twins on average share 50% of human genetic variants. The model further requires assumptions that the environment does not treat MZ and DZ twins differently (Derks et al. 2006) and that there are no gene-environment interdependencies and no trait-relevant assortative mating (for a detailed discussion see Visscher et al. 2008). Without assortative mating, the average genetic correlation for DZ twins is 0.5. Assortative mating increases this correlation. Since we know that assortative mating is present for education and cognitive ability (e.g. Blossfeld 2009; Plomin and Deary 2015), we adjusted for it in the estimation of the variance components. We followed the approach outlined with Loehlin et al. (2009), which suggests that the DZ correlation with assortative mating is $0.5 + 0.5 \times h^2 \times r_p$, with h^2 being the standardized additive genetic variance (σ_A^2/σ_P^2) and r_p being the phenotypic correlation between parents. This leads to DZ correlations of 0.6 for the CFT as well as academic tracking.[3] We fit structural equation models separately to the cognitive ability and academic tracking data on the basis of these assumptions using Mplus 7.4.

To estimate how family resources affected cognitive ability and tracking, we used two level multilevel models (linear and logit) including siblings of the twins. For a continuous dependent variable, the model was given by:

$$y_{ij} = \mu + X_{ij}\beta + u_j + \varepsilon_{ij} \qquad (2)$$

where j denotes level 2 (family) and i denotes level 1 (family member). X_{ij} was a vector of covariates and β a vector of the associated regression weights. u_j was the level-2 error and ε_{ij} the level-1 error. For the binary academic tracking variable, the two-level logit model was given by:

$$\ln\left(\frac{p_{ij}}{1 - p_{ij}}\right) = \mu + X_{ij}\beta + u_j \qquad (3)$$

[2] Covariances and interactions among the components are assumed to be zero. This assumption, however, is often violated, perhaps especially in associations among cognitive ability and education and social attainment measures.

[3] In our sample the correlation between both parents' CFT was about 0.4 and between both parents' secondary schooling (binary variable, indicating if a higher secondary track was completed) was about 0.6. Assuming that in general σ_A^2 is around 0.6 for cognitive ability and around 0.4 for education (Branigan et al. 2013; Briley & Tucker-Drob 2013) this leads to a genetic correlation of 0.6 in DZ twins for both outcomes.

where p_{ij} denoted the probability that $y_{ij} = 1$, the upper-level academic track. Unlike in linear models, changes in effect estimates in nested non-linear models, e.g. logit or probit, cannot be straightforwardly attributed to addition of confounding or mediating covariates (Karlson et al. 2012; Mood 2010), due to the need to assume a fixed error variance – the residual variance in the logit model is generally fixed at $\pi^2/3$. Adding a covariate to a logit model changes the variance and hence the scale of the (underlying latent) dependent variable. This changes the estimated coefficients of the original covariates too, even if they are uncorrelated with the new covariate. Coefficient magnitudes in nested logit models should thus not be compared directly. We estimated cluster-robust standard errors to account for possible heteroscedasticity and potential serial correlation within clusters (Wooldridge 2010). These analyses were carried out using Stata 14.2.

We present the intra-class correlation as well as goodness-of-fit statistics for the linear (R^2, Chi^2) and the logistic two-level model (Log likelihoods, Chi^2), which we have averaged over the imputed data sets. Please note that these statistics may lack a clear interpretation when dealing with multiply imputed data sets (StataCorp 2015; White et al. 2011). Thus, they should be interpreted with care, and we abstain from an explicit comparison of model fit.

For both outcomes we present several model specifications that controlled different sets of presumed antecedent variables. When interpreting the effects of antecedent variables one has to recognize that indicated effects were direct – not total – since intermediate covariates were controlled. Interpretation as total effects is unwarranted since inclusion of intermediate covariates can introduce "over-adjustment bias" (Schisterman et al. 2009), which occurs when one controls a presumed intermediate cause on a presumed causal path from exposure to outcome. For instance, if we are interested in the total effect of parental education on children's CFT, controlling parental occupational status will cause an over-adjustment bias, since education can be assumed to cause occupational status. Estimates of antecedent variables may still be interpreted as direct or residual effects, with measured mediating covariates controlled. Importantly, in the models that predict academic tracking, we explicitly control for children's CFT. Although the CFT is an intermediate covariate – affected by parental socio-economic status and predictive of academic tracking – our interest lies in in the (remaining) direct effects of socio-economic status net of children's ability. Since children's CFT is already an outcome of socio-economic status, the other covariates' effects are direct effects and not total effects.

We specified our models so that child cognitive ability affected tracking, consistent with models of cognitive ability development as largely genetically-driven (Deary et al. 2010; Dickens and Flynn 2001), though, in our cross-sectional data, we could not exclude the possibility that school tracking had recursive influences running from the distinct school tiers to child cognitive ability.

Results

Descriptive statistics for the sample are displayed in Table 1. The mean age was 14.6 years, with females somewhat over-represented relative to the population at (54%). MZ twins comprised 37%, DZ twins 47%, and 17% were siblings of the twins. The CFT had a mean that differed slightly from zero (mean = -0.04, sd = 0.9) because the full sample with all cohorts and study participants was used to predict the standardized factor scores (see Table A1 in the Appendix), whereas our study was limited the sample to Cohorts 2 and 3 (including further siblings). The majority of twins and siblings was enrolled in (or had completed) the academic track (53%) that opens the path to tertiary education. Intra-class correlations for CFT and tracking (Table 1) showed high resemblances between twins. Similarity was especially high for academic tracking.

– Table 2 about here –

Table 2 presents the results of the variance decompositions. Genetic influences (A) accounted for 60% of the overall variance in CFT, non-shared environmental factors (E) for 37%, and shared environmental factors (C) for only 3%. Variance attributable to genetic influences was thus the largest component. The non-shared environmental component was also substantial, indicating that these influences, along with measurement error, are also important in explaining individual differences in cognitive ability. The shared environmental component was by far the smallest, it appeared negligible. In stark contrast to this, genetic influences accounted for 29% of the overall variation in tracking, shared environmental factors (C) for 66%, and non-shared environmental factors (E) for 6%. Variance attributable to shared environmental influences was thus by far the largest component. While genetic variation was also relevant in school tracking, the non-shared environmental component was very small.

– Table 3 about here –

– Table 4 about here –

Next we investigated how parental social and economic resources impacted CFT and tracking. Table 3 shows the results of cumulative models estimating the associations between children's CFT and parental CFT (Model 1), parental education (Model 2), parental ISEI (Model 3), and net equivalent monthly household income (Model 4) controlling child age and sex. Mean parental CFT was statistically significantly associated with children's CFT (ß = 0.401, s.e. = 0.017, Table 3, Model 1). Parental education was statically significantly associated with children's CFT, even though the presumably important antecedent covariate parental CFT was controlled (Table 3, Model 2). Compared to parents with high levels of education (ISCED levels 5 & 6), children whose parents had medium levels of education (levels 3 & 4) on average scored 0.169 (s.e. = 0.030) less and those whose parents had low levels of education (levels 1 & 2) 0.318 (s.e. = 0.064) less. Parental occupational status was positively and statically significantly associated with children's CFT (ß = 0.004, s.e. = 0.01, Table 3, Model 3). Lastly, net equivalent household income was also associated with CFT (Table 3, Model 4). The expected difference between the CFT of a child from a household whose income was in the fourth quintile and that of a child from a household in the first quintile was 0.132 (s.e. = 0.048) and the difference between the first and the fifth quintile was 0.118 (s.e. = 0.051). A F-test rejected the null-hypothesis that income did not have an overall association with children's CFT (F = 2.45, p = 0.04).

Table 4 shows the results of the cumulative multilevel logit models of the association between academic tracking and parental CFT (Model 1), parental education (Model 2), parental ISEI (Model 3), and net equivalent monthly household income (Model 4) controlling child age and sex. Note that because all models also control children's CFT, the effect estimates of the parental social and economic resources present direct effects and not total effects. The baseline probability is to attend the academic track was about 53%. Children's CFT turned out to being a strong and statistically significant predictor for academic tracking – a unit increase in CFT was associated with an expected change in the odds to attend the academic track by a factor of 4.074 (s.e. = 0.461). Mean parental CFT was also statistically significantly associated with tracking (OR = 4.163, s.e. = 0.598, Table 4, Model 1). Parental education (Table 4, Model 2) was additionally statictically significantly associated: The odds of attending an academic track for children of parents with low (levels 1 & 2) and medium (levels 3 & 4) levels of education were were 0.089 (s.e. = 0.039) and 0.171 (s.e. = .038) times lower than those of a child of parents with high levels of education (levels 5 & 6), respectively. Parental occupational status was positively and statically significantly associated with children's academic track attendance. A unit increase in parental ISEI was associated with an expected change in the odds to attend the academic track by a factor of 1.031 (s.e. = 0.006, Table 5, Model 3). As regards to household income, the odds of attending the academic track for children from households whose income was in the fith quintile were 2.801 (s.e. = 1.083, Table 5, Model 4) times higher than than those of a child from a household from the first income quintile. However, a F-test could not reject the null-hypthosis that income did not have an overall association with academic tracking (F = 2.01, p = 0.09). Thus, considerable direct effects of the antecedent covariates which operationalize parental socio-economic position with respect to parental occupation and parental education remained even when the parents' and the children's CFT was controlled.

Sensitivity Analyses. To examine the robustness of our results, we carried out additional analyses. First, to ensure that the results of the ACE variance decomposition of CFT were robust to the method used to generate the CFT scores, we reanalyzed the data using sum scores instead of factor scores. The estimates (see Table A3, Appendix) were virtually identical. Second, we checked how the variance decomposition on tracking was impacted by the decision to code respondents who were enrolled in comprehensive secondary schools, which can lead to both higher and lower secondary degrees, as 0. Results did not change in any meaningful way when those were coded as 1 (see Table 3, Appendix). Third, we used the alternative CFT sum score in the multilevel models instead of the factor scores (see Table A4, Appendix). The magnitudes of the effects differed, but this due to the difference in scaling between the two scores. Substantially, the results were very similar and led to the same conclusions. Fourth, we inspected the robustness of the multilevel logit model using the alternative coding scheme for tracking (see Table A5, Appendix). Again, the results remained very similar and led to the same substantive conclusions, the comparability problem of logit models notwithstanding.

Discussion

The educational track taken during adolescence exerts a major influence on the life chances of adolescents in Germany (Van de Werfhorst and Mijs 2010). Sociological and psychological perspectives illuminate important pathways to understanding this early benchmark of life chances. The sociological perspective has likely overstated the roles of parental socioeconomic resources in influencing educational attainment when studies have not considered parental and adolescent cognitive ability and the fact that parents transmit both their socioeconomic and genetically influenced personal resources to their children. The focus in much of the psychological literature on the relationship between cognitive ability and educational attainment provides an account of the intergenerational transmission of inequalities that might overlook that different dimensions of socio-economic resources are not interchangeable and do not uniformly affect child outcomes (Bradley and Corwyn 2002).

We have argued that approaches that directly consider the intertwined pathways would offer clearer analyses of the ways the family of origin – in particular parental socioeconomic resources and parental ability – shape children’s cognitive ability and academic track attendance that contributes heavily to eventual educational attainment in Germany. We argued for the importance of separately examining three major dimensions of parental socioeconomic resources to enhance understanding of the social mechanisms of intergenerational transmission and their relative importance. Moreover, while effective measures of improving overall equality of socioeconomic opportunity are often very difficult to identify, some specific components such as family income can be more easily targeted by policy interventions than others.

Our analyses based on the first assessment of TwinLife, a prospective longitudinal study of twins and their families (Diewald et al. 2016), yielded three main findings. First, the degrees to which variation in cognitive ability and academic tracking could be attributed to genetic and environmental characteristics differed substantially. Genetic variation accounted for considerable variance in children's cognitive ability (60%), while shared environmental influences were negligible (3%). In contrast, shared environmental variation appeared to be by far the largest source of variance in academic tracking (66%). This is considerably more than the about 30% found for adult educational attainment (Branigan et al. 2013). Though genetic and environmental variance decompositions are limited to providing bulk quantitative descriptions of specific samples under study, the observed differences implied that the pathways linking the family of origin to children's educational tracking were quite different from those influencing their cognitive ability. Interestingly, the proportion of shared environmental variance for academic tracking was markedly larger than estimates for later educational outcomes. They resembled estimates of shared environment influences on parental educational expectations for twins in kindergarten and fourth grade in the USA (Briley et al. 2014), though not American estimates of shared environmental influences on parental educational expectations at later ages (Johnson et al. 2006; Johnson et al. 2007a; Johnson et al. 2007b). Perhaps, consistent with sociological theories of socioeconomic cultural differences, parental expectations of children's educational prospects at young ages are predominantly shaped by parents' own experiences and values and aspirations for their children and less influenced by children's individual characteristics, but the balance shifts as children own characteristics emerge more clearly and mature. This might make such sociological theories more relevant in countries such as Germany, where academic track decisions are taken early and quite decisively, than in other countries that have more fluid educational systems.

Second, we observed distinct and independent influences of the three dimensions of parental socioeconomic resources. Parental educational level, parental occupational status, and parental income were pairwise correlated with both track attendance and cognitive ability. Thus, it may not be appropriate to lump various dimensions of parental status in composites, as they represent distinct mechanisms in intergenerational status transmission (Erikson 2016:118) and can be differentially relevant to different types of educational success, ability development, and later success in life. Studies that measure socioeconomic resources as composites may mask these differences. Parental educational and occupational resources appeared to influence adolescent cognitive ability and chances of taking the academic track in dose-response fashions. Corroborating earlier studies, we did not find income effects on academic tracking. However, income appeared to be associated with cognitive ability. This finding contrasts with studies from the US in which low levels of income appear to have the strongest effects on adolescent development and educational chances (Brooks-Gunn and Duncan 1997). This could reflect the lower level of income inequality and abject poverty in Germany, and/or suggest that income itself may be less important for adolescents in the German context. Alternatively, our snapshot measures of parental income might not fully capture the accumulation of poverty that is related to lower cognitive ability and educational outcomes. Earlier research in Germany found that longer periods of poverty in early childhood were related to lower educational attainment, indicating that developmental phase and length of exposure to financial hardship impacted children's outcomes (Gebel 2011). In sum, these findings indicate that the different dimension of resources may affect ability and educational attainment distinctively, depending on the larger societal context (Beller and Hout 2006; Korpi 2000; Sørensen 2006).

Our third main observation was that strong direct influences of socioeconomic resources remained after controlling parental cognitive ability, for both outcomes. Similarly, the association between parental socioeconomic resources and academic tracking could not be explained by adolescent cognitive ability alone. In other words, cognitive ability of parents and adolescents did not fully explain the link between parental socioeconomic resources and academic track attendance.

Overall our analyses indicate that it is important to consider both socioeconomic resources and cognitive ability to understand disparities at this first educational hurdle during adolescence in Germany. Moreover, given that socioeconomic resources affected both cognitive ability and educational tracking, their cumulative impact might be substantial.

This study had several limitations that warrant discussion. First, while we found substantial pairwise association between parental characteristics and children's outcomes, parental characteristics are also correlated with each other, making disentangling their independent pathways impossible in our cross-sectional data. Second, while we employed standardized measures of parental education (ISCED) and occupational status (ISEI) that could be considered to be rather stable over the parental life course, income is more variable from year to year. Due to this volatility, our income measure captured a snapshot of financial means at one point in time. Future research could include additional measures of financial resources, such as average or cumulative income over a period of years. Third, it is also unclear whether our observations would hold up when considering other characteristics linking family status and educational outcomes. In this study we considered cognitive ability as one central link between parental status and offspring educational outcomes. Though cognitive ability is clearly an important predictor, non-cognitive traits such as personality, motivation, and aspirations have also been shown to contribute substantially to educational attainment (Farkas 2003; Heckman et al. 2006; Lleras 2008). Non-cognitive characteristics are likewise substantively genetically influenced and correlated genetically with educational achievement (Krapohl et al. 2014). Fourth, genetic and environmental influences on all these characteristics and social status indicators are clearly correlated in Germany and most "developed" countries, violating one of the primary assumptions underlying the models we fit. These correlations and the possible interactions usually associated with them distort estimates of variance components and the main effects such as those presented here. Thus, a complex interplay of genes and environmental characteristics could have obscured the main effects of parents' and children's cognitive ability. It is a general limitation of our models that they are highly contingent on social structural and developmental contexts (Tucker-Drob et al. 2013), so models that address these possibilities more directly need to be developed and applied in future studies (South et al. 2015) Fifth, having only the first TwinLife assessment available, we could report only cross-sectional associations. We cannot rule out reverse causation. Tracking might well impact development of cognitive ability, as might previous success in school (Becker et al. 2012). Once subsequent TwinLife assessments are available, future research has to examine whether our present observations hold.

Conclusion

Overall, our results suggested that mainstream interpretations in psychological and sociological research have been too simple: Neither was parental cognitive ability the sole factor underlying observed correlations between parental resources and children's' outcomes nor did parental resources for educational attainment work only via ability development. Likewise, we observed a paramount role for intergenerational transmission of ability in influencing adolescents' life chances.

In this respect, our analyses were a starting point in a more comprehensive endeavor to integrate state-of-the-art concepts from various disciplines. Distinct dimensions of parental socio-economic resources can have independent influences on cognitive ability and track attendance depending on the societal context. Studies that measure socio-economic resources in the form of single or composite measures may fail to account for the extensive influences of social background on both cognitive ability and educational attainment. Moreover, decomposition of variance into genetic and environmental components indicated that the proportion of shared environmental variance in academic tracking was markedly larger than estimates for educational outcomes. This could be specific to stratified education systems like Germany's, in which academic track decisions are taken early and quite decisively, when it is very difficult to judge children's future development. This underscores research that has indicated that in educational systems with early tracking parental background plays a large role in influencing adolescents' educational pathways. In contrast, adolescent cognitive ability, likewise a strong influence on educational tracking, was much more genetically influenced and less influenced by shared environment. Whether this marked difference characterizes specifically the German experience of adolescence or defines a more general pattern has to be shown by future research.

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Table 1. Sample descriptives

	Mean/prop. of sample	sd	min	max	Number missing	Intra-class correlation MZ (DZ)
Child						
Age	14.60	3.29	10	31	0	
Gender (0=female)	.46		0	1	0	
CFT score	-.04	0.90	-3.38	1.88	207	.73 (.53)
Academic track	.53		0	1	223	.96 (.86)
Child type						
MZ	.37		0	1	0	
DZ	.47		0	1	0	
Sibling	.17		0	1	0	
Family characteristics						
Mother present in household	.97		0	1	0	
Father present in household	.78		0	1	0	
Both parents present in household	.75		0	1	0	
Mean parental CFT	-.06	0.83	-3.18	1.67	136	
ISCED level 1 & 2	.06		0	1	59	
ISCED level 3 & 4	.37		0	1	59	
ISCED level 5 & 6	.57		0	1	59	
Net equiv. household income (€)	1068.60	823.9	69.8	13953.5	571	
At least one parent working	.90		0	1	56	
Mean parental ISEI	49.50	26.0	0	89	183	
Child N	4809					

Source: TwinLife, SUF.

Table 2. Standardized variance estimates for CFT score and academic track

		Proportion of variance	SE	95% CI
CFT	A	.60	.07	.46 - .75
	C	.03	.06	-.10 - .15
	E	.37	.02	.32 - .41
Tracking	A	.29	.06	.16 - .41
	C	.66	.06	.54 - .77
	E	.06	.01	.03 - .08

Source: TwinLife, 1. wave. Imputed data (N=20).
N(MZ)=1838, N(DZ)=2362. CFT age adjusted.

Table 3. Random effects models (linear) for family-resources and parent cognitive ability effects on child cognitive ability (unstandardized coefficients)

	(1)			(2)			(3)			(4)		
	ß		se	ß		se	ß		se	ß		se
Child												
Age	.122	***	(.004)	.123	***	(.004)	.123	***	(.004)	.122	***	(.004)
Gender (0=female)	-.018		(.025)	-.024		(.025)	-.026		(.025)	-.027		(.025)
Mean parental CFT	.401	***	(.017)	.349	***	(.019)	.311	***	(.020)	.303	***	(.020)
Parental ISCED (ref.=5 & 6)												
ISCED level 1 & 2				-.318	***	(.064)	-.182	**	(.068)	-.165	*	(.069)
ISCED level 3 & 4				-.169	***	(.030)	-.083	*	(.033)	-.074	*	(.033)
At least one parent working							-.035		(.057)	-.031		(.058)
Mean parental ISEI							.004	***	(.001)	.003	***	(.001)
Parental income (€, ref=1. quantile)												
2. quantile										.028		(.045)
3. quantile										.056		(.046)
4. quantile										.132	**	(.048)
5. quantile										.118	*	(.051)
Constant	-1.793	***	(.064)	-1.723	***	(.064)	-1.943	***	(.079)	-1.968	***	(.080)
Child N	4809			4809			4809			4809		
Families	2076			2076			2076			2076		
Intra-class correlation	.346			.336			.329			.328		
R^2 (overall)	.319			.328			.336			.339		
Wald Chi²	1460.007			1556.032			1679.403			1716.699		
Model degrees of freedom	3			5			7			11		

Source: TwinLife, 1. wave. Imputed data (N=20).
Intra-class correlation, R^2, and Chi² averaged over imputed data sets.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4. Random effects models (logit) for family-resources and parent cognitive ability effects on academic track (odds ratios)

	(1)			(2)			(3)			(4)		
	OR		se	OR		se	OR		se	OR		se
Child												
Age	1.056		(.031)	1.071	*	(.032)	1.076	*	(.032)	1.074	*	(.032)
Gender (0=female)	.655	*	(.115)	.619	**	(.108)	.613	**	(.107)	.610	**	(.106)
CFT score	4.074	***	(.461)	3.858	***	(.432)	3.746	***	(.418)	3.711	***	(.412)
Mean parental CFT	4.163	***	(.598)	2.711	***	(.376)	2.163	***	(.304)	2.084	***	(.293)
Parental ISCED (ref.=5 & 6)												
ISCED level 1 & 2				.089	***	(.039)	.179	***	(.081)	.199	***	(.091)
ISCED level 3 & 4				.171	***	(.038)	.293	***	(.068)	.313	***	(.072)
Parent(s) working							.308	**	(.120)	.322	**	(.125)
Mean parental ISEI							1.031	***	(.006)	1.026	***	(.006)
Parental income (€, ref=1. quantile)												
2. quantile										1.268		(.369)
3. quantile										1.345		(.401)
4. quantile										1.656		(.575)
5. quantile										2.801	**	(1.083)
Constant	.775		(.343)	1.406		(.618)	.652		(.367)	.545		(.313)
Child N	4809			4809			4809			4809		
Families	2076			2076			2076			2076		
Intra-class correlation	.753			.744			.741			.738		
Log likelihood (null)	-2775.902			-2775.902			-2775.902			-2775.902		
Log likelihood (full)	-2469.091			-2422.469			-2405.197			-2399.255		
Wald Chi²	311.337			327.048			334.051			337.977		
Model degrees of freedom	4			6			8			12		

Source: TwinLife, 1. wave. Imputed data (N=20).
Intra-class correlation, log likelihoods, and Chi² averaged over imputed data sets.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A1. Factor loadings of the four subtests of the CFT

	factor Factor loadings	Uniqueness
Figural reasoning	.741	.451
Classification	.727	.471
Matrices	.798	.364
Topology	.591	.651

Source: TwinLife, 1. wave. (N=13326).

Table A2. Pairwise correlations between covariates.

	CFT score	CFT score (alt. cod.)	Tracking	Tracking (alt. cod.)	Age	Gender	Mean parental CFT	ISCED level 1 & 2	ISCED level 3 & 4	ISCED level 5 & 6	Net equiv. monthly hh income	Parent(s) working	Mean parental ISEI
CFT score	1.00												
CFT score (alt. cod.)	0.99***	1.00											
Tracking	0.38***	0.38***	1.00										
Tracking (alt. cod.)	0.35***	0.34***	0.92***	1.00									
Age	0.43***	0.43***	0.09***	0.07***	1.00								
Gender	0.01	0.01	-0.02	-0.01	-0.03	1.00							
Mean parental CFT	0.33***	0.33***	0.30***	0.28***	-0.08***	0.06***	1.00						
ISCED level 1 & 2	-0.15***	-0.15***	-0.16***	-0.14***	0.03	-0.04**	-0.31***	1.00					
ISCED level 3 & 4	-0.12***	-0.13***	-0.21***	-0.19***	0.05***	-0.04**	-0.24***	-0.20***	1.00				
ISCED level 5 & 6	0.20***	0.20***	0.28***	0.25***	-0.07***	0.06***	0.39***	-0.30***	-0.87***	1.00			
Net equiv. monthly hh income	0.14***	0.14***	0.17***	0.17***	-0.05**	0.04*	0.26***	-0.16***	-0.21***	0.28***	1.00		
Parent(s) working	0.14***	0.14***	0.11***	0.09***	0.01	0.03	0.24***	-0.26***	-0.11***	0.23***	0.17***	1.00	
Mean parental ISEI	0.27***	0.27***	0.30***	0.28***	-0.05***	0.06***	0.51***	-0.35***	-0.40***	0.56***	0.36***	0.59***	1.00

Source: 1. wave. N=4809.

Table A3. Standardized variances estimates for CFT score and academic track, alternative codings

		Proportion of variance	SE	95% CI
	A	.58	.08	.43 - .74
CFT	C	.05	.07	-.09 - .18
	E	.37	.02	.33 - .41
	A	.24	.07	.11 - .36
Tracking	C	.69	.06	.57 - .80
	E	.08	.01	.05 - .10

Source: TwinLife, 1. wave. Imputed data (N=20).
N(MZ)=1838, N(DZ)=2362. CFT age adjusted.

Table A4. Random effects models (linear) for family-resources and parent cognitive ability effects on child cognitive ability, unstandardized coefficients

	(1)			(2)			(3)			(4)		
	ß		se	ß		se	ß		se	ß		se
Child												
Age	1.129	***	(.039)	1.137	***	(.038)	1.137	***	(.038)	1.133	***	(.038)
Gender (0=female)	-.043		(.236)	-.103		(.234)	-.119		(.233)	-.130		(.233)
Mean parental CFT	3.686	***	(.158)	3.217	***	(.171)	2.852	***	(.183)	2.788	***	(.185)
Parental ISCED (ref.=5 & 6)												
ISCED level 1 & 2				-2.820	***	(.578)	-1.537	*	(.627)	-1.399	*	(.630)
ISCED level 3 & 4				-1.575	***	(.275)	-.758	*	(.304)	-.683	*	(.304)
Parent(s) working							-.381		(.532)	-.361		(.534)
Mean parental ISEI							.040	***	(.008)	.034	***	(.008)
Parental income (€, ref=1. quantile)												
2. quantile										.291		(.396)
3. quantile										.442		(.419)
4. quantile										1.130	*	(.453)
5. quantile										.967	*	(.466)
Constant	20.547	***	(.575)	21.190	***	(.576)	19.136	***	(.719)	18.915	***	(.729)
Child N	4809			4809			4809			4809		
Families	2076			2076			2076			2076		
Intra-class correlation	.346			.673			.329			.328		
R^2 (overall)	.322			.332			.340			.342		
Wald Chi²	1499.875			1600.777			1730.494			1765.947		
Model degrees of freedom	3			5			7			11		

Source: TwinLife, 1. wave. Imputed data (N=20).
Intra-class correlation, R2, and Chi2 averaged over imputed data sets.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table A5. Random effects models (logit) for family-resources and parent cognitive ability effects on academic track, odds ratios

	(1)			(2)			(3)			(4)		
	OR		se	OR		se	OR		se	OR		se
Child												
Age	1.025		(.030)	1.037		(.030)	1.041		(.030)	1.040		(.030)
Gender (0=female)	.727		(.120)	.693	*	(.115)	.688	*	(.114)	.686	*	(.114)
CFT score	3.359	***	(.339)	3.199	***	(.321)	3.113	***	(.312)	3.090	***	(.309)
Mean parental CFT	3.329	***	(.440)	2.324	***	(.300)	1.881	***	(.246)	1.827	***	(.239)
Parental ISCED (ref.=5 & 6)												
ISCED level 1 & 2				.142	***	(.057)	.274	**	(.116)	.296	**	(.124)
ISCED level 3 & 4				.220	***	(.046)	.368	***	(.081)	.389	***	(.085)
Parent(s) working							.311	**	(.116)	.324	**	(.121)
Mean parental ISEI							1.029	***	(.006)	1.026	***	(.006)
Parental income (€, ref=1. quantile)												
2. quantile										1.251		(.351)
3. quantile										1.177		(.339)
4. quantile										1.429		(.456)
5. quantile										2.471	*	(.870)
Constant	1.686		(.728)	2.832	*	(1.208)	1.423		(.772)	1.230		(.681)
Child N	4809			4809			4809			4809		
Families	2076			2076			2076			2076		
Intra-class correlation	.735			.729			.724			.723		
Log likelihood (null)	-2780.649			-2780.649			-2780.649			-2780.649		
Log likelihood (full)	-2534.250			-2497.970			-2480.609			-2475.451		
Wald Chi²	282.384			298.874			310.090			313.124		
Model degrees of freedom	4			6			8			12		

Source: TwinLife, 1. wave. Imputed data (N=20).
Intra-class correlation, log likelihoods, and Chi2 averaged over imputed data sets.
* p < 0.05, ** p < 0.01, *** p < 0.001.

Author Contributions

W.S. conceived of the study, coordinated and drafted the manuscript; R.S. conceived of the study, performed the statistical analyses and participated in drafting the manuscript; M.D. participated in the design and was involved in the theoretical framework; W.J. contributed ideas to study design, interpretation of the data, analysis and drafting the manuscript. All authors read and approved the final version of the manuscript.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no competing interests.

Ethical Approval All procedures were in accordance with the ethical standards of the German Science Foundation and approved by Bielefeld University.

Informed Consent Informed consent was obtained from all students that participated in the study and their parents.