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Does Parental Education Influence Child Educational Outcomes? A Developmental Analysis in a Full-Population Sample and Adoptee Design

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Children's educational outcomes are strongly correlated with their parents' educational attainment. This finding is often attributed to the family environment—assuming, for instance, that parents' behavior and resources affect their children's educational outcomes. However, such inferences of a causal role of the family environment depend on the largely untested assumption that such relationships do not simply reflect genes shared between parent and child. We examine this assumption with an adoptee design in full-population cohorts from Danish administrative data. We test whether parental education predicts children's educational outcomes in both biological and adopted children, looking at four components of the child's educational development: (I) the child's conscientiousness during compulsory schooling, (II) academic performance in those same years, (III) enrollment in academically challenging high schools, and (IV) graduation success. Parental education was a substantial predictor of each of these child outcomes in the full population. However, little intergenerational correlation in education was observed in the absence of genetic similarity between parent and child—that is, among adoptees. Further analysis showed that what links adoptive parents' education did have with later-occurring components such as educational attainment (IV) and enrollment (III) appeared to be largely attributable to effects identifiable earlier in development, namely early academic performance (II). The primary nongenetic mechanisms by which education is transmitted across generations may thus have their effects on children early in their educational development, even as the consequences of those early effects persist throughout the child's educational development.

Keywords: intergenerational transmission, educational outcomes, full-population studies, adoptees, behavior genetics

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The transmission of social and economic advantage across generations is a perennial topic of interest for both the public and the scientific community. Research on the topic often focuses specifically on education as a pathway through which families reproduce their advantage. The associations between parental and child levels of education are well documented, as are the effects of education on class.

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The data used in this study is owned and controlled by the Danish government, some by Statistics Denmark and some by the Ministry of Children and Education. Researchers interested in obtaining access to this data for replication purposes should apply for access to the registry data. Note that approval for this access is typically only given to a researcher with a position in or affiliated with a Danish research institution and requires payment to the relevant agency. We will transmit replication code for all analyses to researchers receiving approval for data access.

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Precisely how education is transmitted across generations is less clear. Many studies address the question by showing how children's educational outcomes are correlated with a long list of behaviors that are typical of more educated parents (e.g., using a rich vocabulary, providing assistance with schoolwork, or encouraging the pursuit of advanced education). However, drawing causal inferences from studies of this design is problematic. Correlations between the characteristics of parents and those of their children very often appear to reflect not the causal influence of parents on children but instead the role of genes shared by both (Turkheimer, 2000).

Behavioral genetic study designs represent a useful alternative approach. They rely on natural experiments, such as twinning and adoption (Haugaard & Hazan, 2003), in which the degrees of genetic relatedness between family members deviate from that in the typical family. Analyzing such families provides a useful examination of claims regarding parental influence on child characteristics. Consider a situation in which parent and child characteristics are associated primarily or even exclusively in families where parents and children share genes, and not in adoptive families. This association can be more parsimoniously attributed to genes shared between the parent and child, rather than hypothesizing a causal influence of the parent's characteristics on the child's characteristics. Such conclusions can be further buffered when sibling or twin analyses also indicate little or no role for the family rearing environment.

Behavioral genetic studies are even more valuable when they can be used not only to separate the influence of genes and family environment, but also at what points in children's educational development that family environment is most influential. McGue and colleagues (2017) provided a particularly illuminating example. Consistent with previous findings that an adoptive parent's educational attainment could predict both their adoptive child's IQ (Kendler, Turkheimer, Ohlsson, Sundquist, & Sundquist, 2015; Neiss & Rowe, 2000), as well as their educational attainment (Bjorklund, Lindahl, & Plug, 2006), McGue and colleagues (2017) found that the link between parents' education and children's IQ and educational attainment was present but much weaker in adoptive than biological families. Even more intriguing, a (weak) relationship between parental and child attainment among adoptive families remained even after controlling not only for the child's IQ but also for academically relevant socioemotional characteristics. This is an important finding: Parental behavior or characteristics had nongenetic influences on the child's educational attainment not only through IQ but seemingly also through subsequently developing pathways. Facilitating the identification of such nongenetic intergenerational pathways is tremendously important, as these pathways may represent intervention opportunities for remedying the decreased opportunities available to children raised by less-educated parents.

The principle can be illustrated with two of the candidate mechanisms McGue and colleagues (2017) suggested for future exploration: "academic expectations" and "the economic benefits of having wealthy parents." Suppose a major nongenetic mechanism by which families reproduced their level of educational attainment across generations was parents' economic ability to hire private tutors for their children in high school (Davies, 2004). In that case, interventions providing tutors to children from low-education households would eliminate one of the advantages received by children in high-education households, and thereby reduce the nongenetic intergenerational transmission of educational attainment. However, such interventions may have no such effect if the primary nongenetic mechanism was related to academic expectations and aspirations established earlier in children's lives.

The list of potential nongenetic mechanisms of intergenerational transmission of attainment is prohibitively long and diverse. This reflects, in part, the fact that the developmental periods during which such mechanisms could be influential are also long and diverse, encompassing everything from infancy to young adulthood. A fruitful first step in the identification of these mechanisms is thus to attempt to narrow down the developmental periods during which these mechanisms have their effects. To accomplish this, researchers can break down educational development into smaller chunks of time, as well as separate discrete stages that are often unnecessarily conflated in existing work. (For example, rather than looking exclusively at completion of a stage of education, one can also separately analyze enrollment in that same educational stage.) As described further below, when pairing this more detailed analysis with behavior genetic methods, we can identify the developmental periods during which parental attainment appears to exhibit nongenetic associations with child educational development. In doing so, we facilitate the future identification of causal mechanisms by which parents' educational attainment influences their child's education.

In the present study, we analyze the linkage between parental attainment and several separate components in their children's educational development using an unparalleled data resource: Administrative registers on a Danish national sample, allowing a comparison of results in the full population against those in adoptees reared by nonfamily members. We use this to critically examine not only the existence, but also the timing, of any nongenetic effects of parental attainment on child attainment.

Pathways of Influence

In Figure 1, we outline four components of a child's educational development about which the Danish registries contain information. These are: (I) the child's educationally relevant psychological characteristics (which in our study involves only Conscientiousness, but conceptually would also include traits like intelligence); (II) the child's academic performance throughout the compulsory schooling years; (III) the child's enrollment in advanced education; and, (IV) the child's completion of advanced education (i.e., attainment).

The pathways connecting these components, illustrated by the horizontal black arrows (labeled *a*, *b*, and *c*), represent the effects of a component on those listed later in the sequence: High conscientiousness contributes to strong academic performance (*a*); strong academic performance facilitates enrolling in advanced education (*b*); and enrolling in advanced education is required for (but does not guarantee attainment of) that education (*c*).

Genetic (*g*) and nongenetic (*ng*) pathways between parental education and each child component (I-IV) are also labeled. Adoption studies discussed above have compellingly evidenced the first pair of these (genetic and nongenetic associations between parental education and component I, the child's educationally relevant psychological characteristics—i.e., g_I and ng_I). Two of these pairs

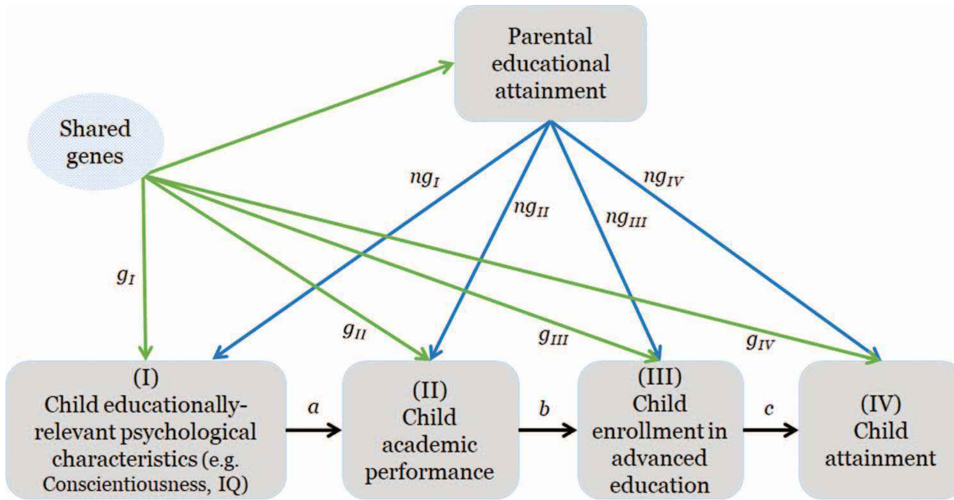

Figure 1. Conceptual diagram of potential connections among parental educational attainment and four components of the child's education. Paths *a–c* represent the effects of one educational component on a subsequent component. Paths g_I to g_{IV} reflect genetic influences shared between parental attainment and a given component of the child's education. Paths ng_I to ng_{IV} reflect nongenetic effects of parental attainment on the corresponding component of the child's education. See the online article for the color version of this figure.

of paths have yet to be addressed by published research—both genetic and nongenetic paths connecting parental attainment with (II) child academic performance (g_{II}, ng_{II}), as well as with (III) child enrollment in advanced education (g_{III}, ng_{III}). Evidence from McGue et al. (2017) supports the final pair of paths—genetic (g_{IV}) and nongenetic (ng_{IV}) connections between parental and child attainment (IV). Importantly, Figure 1 shows how the present study may promote reconsideration of these last results. Specifically, any correlations between parental and child attainment—whether of a genetic or nongenetic nature—may be best accounted for by paths to a preceding component (e.g., g_{III}, ng_{III}), which then proceeds to effect child attainment (via path *c*).

This logic allows us to critically examine both genetic and nongenetic paths between parental attainment and each of components II–IV—though our analyses of component I will necessarily be less comprehensive due to our lack of data on any putative preceding stage. Tutoring can again serve to illustrate: If one reason the children of high-education parents exhibit strong academic performance is that such parents are more able or prone to hire private tutors (Davies, 2004), this might improve the child's academic performance (II) without first affecting the child's educationally relevant psychological characteristics (I). Crucially, this would imply more than simply a significant nongenetic link between parental attainment and child academic performance—which is to say, a correlation between parental attainment and child academic performance among adoptive families. Specifically, it would imply a link that persists after controlling for the child's educationally relevant psychological characteristics—in the terminology of Figure 1, that ng_{II} is significant and positive even in a model that simultaneously assesses ng_I and *a*. If, alternatively, the path from parental attainment to child academic performance (ng_{II}) is nonsignificant in such a model, that casts doubt on whether mechanisms such as tutoring effectively account for intergenerational transmission of education.

Prior work has been severely limited in their ability to explore these issues given that no genetically informative study has ever tried to integrate any but the first and last components identified in Figure 1. Given the vast amount of both educational and personal development that occurs between these first and last components, we thus have little existing basis for evaluating the timing of any nongenetic effect of parental attainment on child educational development. We can recognize the importance of resolving such questions of timing by imagining various possible results from our analysis. Consider if we found that children of educated parents enrolled in higher education at rates above what would be expected based on their prior academic performance and do so for reasons unrelated to genetics—that is, a significant ng_{III} path. This would comport with accounts in which educated parents use resources or social connections to facilitate the child's admission to advanced education, or in which they convince their children that advanced education is sufficiently important that it should be pursued even when one's prior academic performance makes future educational success appear less than certain. By contrast, if ng_{III} is *not* significant while a nongenetic path from parental education to child academic performance (i.e., ng_{II}) *was*, more attention might instead be paid to how educated parents improve their children's academic performance rather than specifically facilitating or encouraging enrollment in advanced education.

The present study, then, will help evaluate various potential mechanisms by which parental attainment might influence child educational characteristics by identifying whether parental education's association with that child characteristic persists after not only eliminating genetic confounding (i.e., when studying adoptees) but also after additionally controlling for the child's prior educational development.

The Present Study

We use data collected by the Danish government for administrative purposes to explore the associations between parental levels of education and the four child educational characteristics described above. To assess educationally relevant psychological characteristics (Component I in Figure 1), we use the child's level of conscientiousness, a personality trait highly relevant for academic performance. (Childhood data on other pertinent traits, such as openness to experience and intelligence, are unfortunately not available in Danish registry data, but because conscientiousness is the most potent Big Five trait for predicting academic performance [Poropat, 2009], it bears examination.) Academic performance (II) is assessed via standardized national tests taken throughout the child's education (Grades 2, 4, 6, and 8) as well as with exit exams taken at the completion of compulsory education (9th grade). Enrollment in advanced education (III) is assessed using enrollment in the most academically rigorous postcompulsory educational track (high school, also referred to as gymnasium), which is pursued by the most gifted two thirds of Danish students and typically begins in the year students turn 17, as described below. Attainment (IV) refers to completion of high school, which is itself a rigorous and selective accomplishment: In our high school completion sample described below, only 85% of students enrolled in this 3-year degree in 2010 completed it by 2016 (analyses described in Supplementary Materials S2 in the online supplemental material). For reasons discussed below, the analyses using conscientiousness are limited to public school students (80% of the population in the relevant cohort), but all other analyses use all Danish residents within the relevant age ranges.

This data provides a number of advantages over previous studies. First, the use of administrative data provides advantages with respect to:

1. statistical power (our sample sizes are far larger than those found in typical adoption studies),

2. data accuracy (e.g., parental education is not vulnerable to inaccurate self- or child-reporting),

3. generalizability (as no analyses are affected by concerns such as volunteer bias, and most analyses use the entire population of a given age cohort), and

4. completeness (as we can supplement our primary, intergenerationally focused analyses with traditional sibling comparisons to analyze genetic and environmental contributions).

A second class of advantages pertain to our Conscientiousness data: Although the measure is very brief, it

5. captures precisely the domain of greatest relevance for the topic in question, and

6. does so at the ages that are not only most relevant for the topic (i.e., before one has completed one's education) but are also when parental characteristics have a greater opportunity to affect the child—that is, when the child is comparatively young and still living in the family home (Bergen, Gardner, & Kendler, 2007).

The final strengths are perhaps the most important. These are that we

7. remedy the previous lack of genetically informative studies of parental attainment on child academic performance and enrollment in advanced education through our use of adoptee subsamples, and

8. in simultaneously analyzing such a range of components of childhood education, we have an unsurpassed ability to highlight any stages at which a specific nongenetic role for parental attainment on a given child characteristic are more or less plausible.

Materials and Methods

Because the administrative data we analyze was collected by the Danish government for purposes unrelated to the present study, many elements of the data are available only for a specific subset of the population. As data availability determines the sample used for a given analysis, we begin by describing the measures used for each characteristic before describing the samples. More extensive discussions of measures and samples, both with details to facilitate replication and an extended discussion of how data availability shaped the parameters for a given sample, are provided in Supplementary Materials S1 in the online supplemental material.[1]

Permissions and monitoring pertaining to ethical and legal use of the data was obtained by registering the project with The Danish Data Protection Agency (Registration 2016-051-000001), which is the independent authority that supervises compliance with the rules on protection of personal data.[2]

Measures

Conscientiousness (Component I). Students enrolled in Danish public schools completed an annual assessment on well-being beginning in 2015, with data currently available through 2017. Three items completed by 4th to 9th graders were judged by the

[1] Note that there is no central repository or list of published work using Danish registry data to readily identify how different studies have used this data. A segment of the same participants studied here were used to explore a non-focal result reported below, namely the link between Conscientiousness and test scores (Andersen et al., 2020). Other studies have used full-population Danish cohorts older than the children analyzed here to look at how parental education predicts child educational attainment and 9th grade exam performance, though without exploring comparable conditional analyses to those performed here (Andrade & Thomsen, 2018; Landersø & Heckman, 2017). Most importantly, no work appears to have used any segment of the adoptees analyzed here to explore intergenerational transmission of education or any related characteristic.

[2] The data used in this study is owned and controlled by the Danish government, some by Statistics Denmark and some by the Ministry of Children and Education. Researchers interested in obtaining access to this data for replication purposes should apply for access to the registry data. Note that approval for this access is typically only given to a researcher with a position in or affiliated with a Danish research institution and requires payment to the relevant agency. We will transmit replication code for all analyses to researchers receiving approval for data access.

authors to reflect Conscientiousness as reflected in the Big Five—particularly the agentic/industrious rather than orderly components of the trait. The Danish text for the items is provided in the online supplementary materials. English translations of these items are

- "How often can you complete what you set out to do?"
- "Can you concentrate during class?"
- "If interrupted during lessons, I can quickly concentrate again."

Results from a supplementary study described in Supplementary Materials S1 in the online supplemental materials indicated that this brief measure not only correlated highly ($r = .65$) with a general measure of Big Five Conscientiousness (John & Srivastava, 1999), but that it was particularly characterized by the conscientiousness facets of self-discipline, self-efficacy, and achievement. Previous research suggests that a Conscientiousness measure with this facet profile should be a comparatively effective predictor of academic performance (Chamorro-Premuzic & Furnham, 2004). This was also recently confirmed by a recent study on the present data (Andersen, Gensowski, Ludeke, & John, 2020).

For each year's assessment, we generated a sum score for each participant and then standardized the score ($M = 0$ and $SD = 1$). We then averaged across each participant's scores as they were available over the period 2015–2017. (For some participants, e.g., those too young to complete the first- or second-year's assessment, the average involved scores from only one or two years.) This average score was then standardized again. Considering the brevity of the measure, internal consistency was high at all grade levels (alphas ranged from .68 to .70), and test-rest correlations were substantial (e.g., $r = .55$ between 2016 and 2017).

Academic performance (Component II). The available registry data allowed us to analyze the second component in Figure 1, that is, academic performance, with both a comprehensive measure of exit exams as well as a developmentally informative assessment of Danish language skills at multiple ages.

Danish national tests. Since 2010, Danish public-school students in 2nd, 4th, 6th, and 8th grade are required to take a test of their reading ability near the end of the school year. These Danish national tests are computerized adaptive tests in which items are determined by the student's performance earlier in the test. The test is scored electronically without teacher input, such that the system automatically calculates scores in three performance areas: Language comprehension, decoding, and reading comprehension. Following previous practice with this data (Nandrup & Beuchert-Pedersen, 2018; Sievertsen, Gino, & Piovesan, 2016), we standardized these three individual scores, took the simple average, and restandardized them within each year. For analyses in which we used conscientiousness as a predictor of test scores, we formed a multiyear composite score, using the average of the available Danish national test scores between 2014 and 2017 for each individual. Of note, Danish students also take tests in mathematics in Grades 3 and 6. We focus on the reading exams due to the lesser frequency of the math tests, but supplementary analyses (Supplemental Table S3 of the online supplemental materials) showed the results were highly comparable when using math scores as a measure of academic performance.

Exit exams. A comprehensive set of exit exams are completed by all Danish students (not just those in public school) at the end of 9th grade. Since 2007 these exams have included a stable set of mandatory exam topics (written and oral Danish; reading; spelling; mathematical problem-solving; mathematical skills, oral science [physics and chemistry]; and oral English). Although these exams represent a diverse array of content and assessment procedures, they are highly correlated. Analyses within a sample described below (Sample 3a) showed a mean correlation among the scores on the eight tests of .50 (range of individual intertest *r*s were .41–.80). We took the mean of the eight exams and then standardized this mean score among all students providing complete exit exam data.

Higher educational enrollment (Component III) and attainment (Component IV). In the Danish educational system, the first opportunity for students to select into rigorous advanced education comes after the completion of 9th grade, at which point they can enter academic high school. We analyzed the enrollment decisions of those who were in 9th grade (either public or private) in the 2009–2010 academic year and found that only 71% of these students will have enrolled in this advanced educational track by 2016.

Because of the young age of the children in our study (discussed below), we used high school for our child measures of both advanced educational enrollment and completion, consistent with similar work facing comparable age limitations (Ayorech, Krapohl, Plomin, & von Stumm, 2017).

Parental educational attainment. The older age of the parent generation allowed us to use a continuous measure of overall educational attainment, which is generally preferable. Specifically, for parents we used registry-based information about the highest educational level achieved and assigned the standard duration of each educational program as the individual's "years of education." We took the mean score of both legal parents to represent the average parental education in years. When data was missing for one parent (as it is for 1.7% of children enrolled in Danish public elementary school in 2015), the mean parental education variable was simply the score for the one parent with data. Operationalizing parental education differently (dichotomizing parental educational attainment based on the completion of specific advanced degrees) produced no meaningful changes to results (Supplemental Tables S4.a and S4.b in Supplementary Materials S3 in the online supplemental material).

Participants

The various assessments discussed above are available for different time frames, such that no individual had meaningful data on all four components of child educational development discussed above. For example, students young enough to have completed the conscientiousness measure will not have had a chance to have their high school graduation recorded in the Danish registries. Accordingly, we conducted our analyses not on a single sample of participants providing all relevant data but on several, often-overlapping samples defined as described below. All samples shared one criterion, namely that parental education data must be available for at least one legal parent. We always contrast the full population (designated Sample *N*a) with the subsample of nonfamily adoptees (Sample *N*b)—more information on adoptees below.

Note that characterizing and critically evaluating the present study's statistical power presents a few challenges. Some standard concerns do not apply: For example, we use secondary data and the present study is not hypothesis-based, such that worries like "optional stopping" of data collection appear irrelevant. In addition, the sample sizes for individual analyses are exceptional, running between 2,000 and 465,000 individuals. Related to the large sample sizes and lack of hypotheses is the fact that we do not see a way to identify a straightforward threshold below which results would not be interesting: The outcomes studied here are of substantial social and personal importance, and so in what follows we will interpret with interest even effect sizes that are a third as large as what current conventions label a "small" ($r = .10$) effect.

Samples 1a and 1b—High school (Component IV). Members of Samples 1a and 1b were all those born between 1988 and 1993, reflecting limitations in the dates of available information on adoptive status (adoption data is not available prior to 1988) and high school completion, as described in Supplementary Materials S1 in the online supplemental materials. Table 1 presents a breakdown of data availability (for this and all other samples), which highlights how many participants were eliminated by a given restriction. For the present sample, the table shows that of the 477,384 individuals recorded in the Danish registry with birthdays in the years 1988–1993, we lacked parental education data for 14% (who are overwhelmingly children of immigrants), leaving us with a final sample of 412,295 for Sample 1a. Sample 1b consists of the 3,297 Sample 1a members who are "nonfamily" adoptees (described more below).

Samples 2a and 2b—Exit exams (Academic Performance: Component II) and high school enrollment (Component III). Samples 2a and 2b included those taking the exit exams between 2007 (the first year the procedure for this period was adopted) and 2014. Of the 545,792 people enrolled in 9th grade (public or private) between August, 2007 and June 2014, 1% were lost due to missing parental education data, and 14% were missing ninth-grade exit exam data, leaving us with 465,358 individuals in Sample 2a. Sample 2b consists of the 3,505 Sample 2a members who are nonfamily adoptees.

Sample Collections 3a and 3b—Assessing paths within academic performance. The availability of multiple years of academic performance data using the Danish national tests allows for fine-grained analyses of the second component in Figure 1—that is, analyses of the development of academic performance between 2nd and 8th grade. Specifically, this allows us to conduct the same type of analyses as discussed above to allow us to search for genetic and nongenetic effects on academic performance that are specific to a given age. For this, we created three samples: One with all who completed reading tests in both 2nd and 4th grade; one with data from both 4th and 6th grade; and a third with data from both 6th and 8th grade. Participants completed these tests between 2010 and 2017. 514,847 individuals were thus included in one or more of these samples for the full population analyses, and 3,815 were included in the various adoptee samples. For the analyses of Grades 2–4, the full (adoptive) N was 300,298 (2,049); for Grades 4–6, 297,138 (2,293); for Grades 6–8, 274,098 (2,170).

Samples 4a and 4b—Conscientiousness (Component I) and performance on Danish national tests (Component II). Participants in these samples include all students who completed one or more of the annual well-being assessments performed in 2015–2017 and completed a Danish national test in reading between 2014 and 2017. A total of 536,593 children were enrolled in Grades 4–9 in any Danish school during the years 2014 to 2017, with approximately 80% enrolled in public schools (for which these assessments were mandatory) at any one point in time. Less than 2% of public-school students were eliminated due to missing data on parental education, and 11% were eliminated due to lack of a conscientiousness score. Less than 5% of the remaining children lacked data on the Danish national tests. The final N for Sample 4a was 392,163. Sample 4b consisted of the 2,799 nonfamily adoptees in Sample 4a.

Adoptees. The Danish Civil Registration System records not only whether an individual is legally adopted by another person but also whether that adoption was performed by a nonfamily member—that is, those not performed by a relative or a step-parent. Because our adoptee analyses are intended to eliminate all potential genetic confounding, we analyzed only these nonfamily adoptions. The concern with genetic confounding is also an issue for the sibling analyses we conduct. Because information on the adoptees' birth parents is not available in the Danish registries, we sought to reduce the likelihood that two adoptees share birth parents by eliminating pairs of adoptees who were adopted on the same day from all analyses of adoptive sibling correlations.

Table 1
Breakdown of Participant Loss in Individual Samples

	Sample 1		Sample 2		Sample 4	
	Born between 1988 and 1993		Enrolled in ninth grade between August 2007 and June 2014		Enrolled in fourth–ninth grade January first 2014–2017	
Variable	Full population	Nonfamily adoptees	Full population	Nonfamily adoptees	Full population	Nonfamily adoptees
Initial sample size	477,384	3,348	545,792	4,375	536,593	4,222
Enrolled in public school January first	NA	NA	NA	NA	458,901	3,362
Parental education data for at least one parent available	412,295	3,297	539,865	4,359	452,422	3,361
Conscientiousness data available	NA	NA	NA	NA	404,751	2,940
Academic performance measure available	NA	NA	465,358[a]	3,505[a]	392,163[b]	2,799[b]
Final N for analysis	412,295	3,297	465,358	3,505	392,163	2,799

Note. NA indicates the restriction does not apply to the sample, thus leading to no loss of participants.
[a] Ninth-grade exit exams. [b] National test in Danish language.

Of the 8,784 individuals distributed throughout our various adoptee samples (1b, 2b, 3b, and 4b), 56% are female, and represent a total of 51 countries of birth. The median age at adoption in these samples is 15.4 months, with 75% completed by 28.3 months. Adoption procedures vary based on country of child origin, with some (e.g., South Korea) exhibiting a low (10.7 months) average age of adoption, whereas others (e.g., Thailand) were considerably later (51.3 months). Adoptive parent attainment was minimally associated with salient characteristics of the adoptee. More educated parents were trivially but statistically significantly more likely to adopt younger children (r with child age at adoption $= -0.03$ [-0.06, -0.01]), and slightly more likely to adopt children from less developed countries as scored using the 2007 Human Development Index (HDI) scores (r with HDI $= -0.07$ [-0.10, -0.05]).

The registry data also provides insights into the similarities and differences between adoptive and nonadoptive parents. Parents of the children in our adoptive samples were not immune from the challenges of life, but they did experience them at lower rates than did parents in our full samples. Compared to the adoptive samples, the full samples had parents who were more likely to: not be married to the child's other parent (42%); have ever been imprisoned (recorded since 1980; 16%); and have a psychiatric diagnosis recorded in the registers between 1977 and 2014 (17%). However, parents of adoptees also faced these situations with some frequency (22%, 4%, 8%, respectively). Parents differed more markedly on immigration status: Although children in our adoptive and nonadoptive samples had similar rates in which only one of two parents was an immigrant (5% and 7%, respectively), very few adoptees were raised in families in which *both* parents were immigrants (0.6%), whereas 9% of nonadoptive children were in such families. Finally, adoptive parents were somewhat more educated (mean years of education = 14.96) than were nonadoptive parents (M = 14.10). Crucially, there was meaningful variation within both groups of parents (SD of adoptive/nonadoptive parent years of education = 2.02/2.16). Thus, there remains substantial variation in family experiences within each group of children, and presumably the ability to detect potential impacts of such variation on the child.

A comparison of adoptive and nonadoptive children indicates that, whereas adoptive parents tended to have better-than-average outcomes, the opposite was true for adoptive children. Adoptees enroll in and complete high school at lower rates (58% and 49%, respectively) than same-age peers (62% and 54%, respectively), and they are more likely than their same-age peers to have psychiatric diagnoses (16% vs. 9%) and to be enrolled in special education classrooms (11% vs. 10%). With adoptee results being closer to 50% than are the corresponding full sample results, adoptees could be said to exhibit more variation on these characteristics than does the full sample, but for some continuously scored variables adoptees exhibited slightly attenuated variability. For example, adoptee scores on exit exams and conscientiousness are .32 and .06 SD below the mean, respectively, with only 95% and 97% of the full sample variance, respectively.

Empirical Strategy

Parent–child regressions. Our main empirical strategy is to explore how parental educational attainment predicts each of the components in children's educational development as illustrated in Figure 1. To do so, we used logistic regression for binary outcomes (namely, high school enrollment and completion), and ordinary least squares for continuous education outcomes (namely, conscientiousness and performance on the exit exams and Danish national tests).[3]

To distinguish between genetic and environmental relationships, we ran these regressions separately on the general population of all children and on the subsample of adopted children. Several different inferences can be made based on results from these regressions. The most straightforward concerns the results among adoptees: The presence of a nonzero association between parental education and a child educational characteristic is consistent with nongenetic pathway(s) linking the two. We contrasted these adoptee results with results from the general population. When the association between parental education and the child characteristic is more pronounced in the general population than among adoptees, that is typically taken to indicate the presence of genetic influences with effects on both educational attainment in the parents and the child characteristic in question.

In a next step, we added the child's characteristic from the previous stage as an independent variable in the regressions. We thereby controlled for any influence that parental educational attainment may have had on the children up until that point in their development, in order to see whether parental background exerted a specific influence on the children's later educational development. For example, in a logistic regression with the child's enrollment in advanced education as the outcome (Component III), we added the child's performance on the comprehensive exit exams (Component II) as an additional predictor. Should a nonzero association between parental education and the child outcome still be present in the adoptee sample, that would be consistent with claims of nongenetic pathway(s) *specific* to enrollment in advanced education (Component III).

Sibling correlations. Parent–child analyses can be usefully supplemented by sibling analyses that enable us to evaluate the relative importance of genetics and the shared environment. This is because levels of education in rearing parents are shared by the children in that home, and thus any nongenetic effects of parental attainment are expected to lead to similarity between coresident siblings, even in the absence of genetic similarity between such siblings. Translated into the terminology of standard behavior genetic models, this is to say that nongenetic effects of parental attainment should manifest in sibling analyses as shared environ-

[3] We include an indicator for the child's sex and use cluster-robust estimates of the variance–covariance matrix of the estimators in our regressions. The cluster-robust estimates account for the fact that students are clustered within schools. This clustered nature of the data (on at least one level) could generate a correlation in the error terms of students that attend the same school, and therefore bias the standard errors of our estimates. For assessments that are completed while students are studying at a given school (i.e., exit exams, Danish national tests, and conscientiousness), we cluster at the level of the school where the exams were taken (up to 2,310 institutions). For high school enrollment and completion, we cluster using the school where the student attended 9th grade (up to 2,323 institutions). Note that a few individuals do not have the school indicator available in the registry data (5.8% of sample 1, 0.1% of sample 3, and 0% of samples 2 and 4). These individuals are included in the analyses as if they were independently distributed.

mental effects.[4] Therefore, we analyze sibling correlations for each of the stages of the child's educational development, first for nontwin full biological siblings and then for adoptees. In households where more than two children meet the requirements for inclusion in a given sample, we use only the oldest two children meeting those requirements for our sibling correlation analyses.

Results

We begin our analyses with the outcome of greatest interest—child attainment—and work backward through the child's educational development as outlined in Figure 1.

Educational Attainment

A first indication of the importance of familial influences—whether genetic or shared environmental—on attainment is provided by the significant similarity between siblings in high school completion. Nontwin full siblings from the relevant full sample (1a) exhibited a sibling correlation of .55 (95% CI [.54, .56], 74,938 pairs) for high school completion. In the corresponding adoptee sample (1b), sibling similarity was reduced but still substantial (.25; [.11, .38]; 449 sibling pairs). At 45% of the correlation in the full sample, this result indicates that not only genetics but also features of the shared environment were notable contributors to educational attainment.

Figure 2A allows us to explore whether parental attainment might plausibly account for some of these shared environmental effects. (Full numerical results presented in Table 2.) Although parent–child associations in the general population do not allow us to separate genetic from shared environmental influences, the large size of these associations are still noteworthy: In the full sample (1a), a one *SD* increase above the mean in parental years of education predicted a 16.6 percentage point [16.4, 16.7] increased likelihood of high school completion. Thus, whereas at mean parental education the children completed high school at 55%, the predicted probability of completing high school at one *SD* above the mean in parental education was closer to 72%.

Of even greater interest is the corresponding result in the adoptee subsample, where the difference was 2.9 percentage points [1.17, 4.63]. The fact that this value was nonzero indicates some nongenetic association between parental attainment and child attainment. At the same time, the modest size of this result (only 17% of the result in the full sample) indicates that genes shared between the parent and child accounted for the majority of the covariation between these traits. That is, although the adoptive sibling correlations highlight a significant role for the shared environment as an influence for child attainment, the regression results suggest that whatever aspects of the shared environment contributed to sibling similarity in attainment did not vary markedly as a function of parental attainment. If parental attainment was a highly potent influence on child attainment, or even simply a highly effective indicator of the presence of some other nongenetic causal factor, its association with child attainment in the adoptee sample should be more pronounced.

Nevertheless, because some association between parental and child attainment was evident even among the adoptees, an evaluation of the timing of these effects is merited. For the timing analysis, we created "enrollee" versions of Samples 1a and 1b; all children who had never enrolled in high school were excluded from these samples. We then obtained the mean years of parental education from two subsets of each of these samples: those who completed high school and those who did not.

In the full population (Sample 1a enrollee), these two subgroups had substantially and significantly ($p < .001$, $t = -67.31$) different levels of parental education for completers and noncompleters, respectively ($M = .19$ [$SD = .89$] vs. $M = -.18$ [$SD = .92$]; Cohen's $d = .36$). By contrast, among adoptees (Sample 1b enrollee) parental education was not significantly different between completers and noncompleters ($M = .36$ [$SD = .92$] vs. $M = .38$ [$SD = .86$]; Cohen's $d = -.03$, $p = .64$; $t = 0.47$). Thus, we found no evidence of a nongenetic contribution of parental education that was specific to child attainment, which is to say there is no evidence for the existence of path ng_{IV} from Figure 1. Instead, all nongenetic contributions to child attainment appear to have been introduced earlier in educational development and transmitted via path *c*. By contrast, there was evidence of a role for *genetic* contributions that were specific to child attainment—that is, g_{IV} is positive and nonzero. This is evidenced by the fact that among the full sample, parental education was highest among children who completed high school even when they were compared against fellow high school enrollees, and to an extent that was considerably more pronounced than was the case among the adoptee sample.

Enrollment in Advanced Education

Results for advanced educational enrollment are highly parallel to those for attainment. First, high school enrollment was substantially familial: The sibling correlation among nontwin full siblings from the corresponding sample (2a) was nearly identical to that for completion ($r = .54$ [.53, .56], 63,191 sibling pairs). However, the characteristic may be comparatively more influenced by the shared environment and less influenced by genetics, as the correlation in the corresponding adoptee sample (2b) was somewhat larger than that for educational attainment ($r = .30$ [.14, .41], 414 sibling pairs, 55% of the effect in the full sample).

Similarly, parental attainment substantially predicted enrollment in advanced education: As shown in Figure 2B as well as Table 2, students with 1 *SD* higher parental years of education were 11.0 percentage points [10.9, 11.1] more likely to enroll in high school in the corresponding full sample. As with child attainment, however, this effect was much smaller among the adoptees, among whom the corresponding value was only 2.2 percentage points [0.8, 3.6]. As with child attainment, this result indicates some nongenetic role for parental attainment on child enrollment in advanced education, even though the modest size of this result (only 20% of the result in the full sample) indicates that genes shared between the parent and child accounted for substantially more of the covariation between these characteristics. Thus, although the adoptive sibling correlations highlight a significant role for the shared environment as an influence for child educational enrollment, whatever aspects of the home environment contributed

[4] This, of course, depends on the assumption that a particular "objective" feature of the shared environment—here, parental education—is also "effectively" shared for the children, in that it affects all children in a given home in generally similar ways.

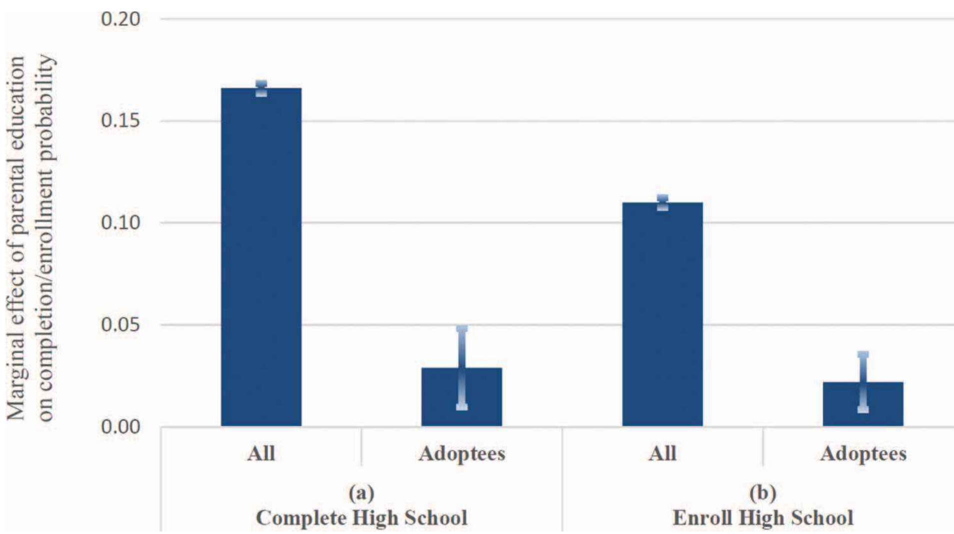

Figure 2. Predicted differences in the probability of child's high school completion and enrollment based on parental education. Shown are differences in probabilities (marginal effects) corresponding to a change of one standard deviation of parental education after estimating the binary outcome of completion/enrollment with logistics regression, with the 95% confidence intervals as whiskers. See full numerical results in Table 2. See the online article for the color version of this figure.

to sibling similarity in enrollment do not appear strongly related to parental attainment.

A final apparent parallel between the results for attainment and those for enrollment is the most important: Just as limiting the high school completion analyses to the enrollee subsample eliminated any nongenetic effect of parental attainment, conditioning on academic performance (as assessed with 9th-grade exit exams) reduced the effect of adoptive parental attainment on adoptive child enrollment by two thirds, rendering it nonsignificant (adoptee conditional result [i.e., ng_{III}] = 0.8 percentage points [−0.34, 1.92]). By contrast, the full sample result remained significant, though similarly diminished (3.1 percentage points [3.0, 3.2]). With this result not only significant, but significantly larger than the corresponding result among adoptees, pathway g_{III} is supported.

The strong reductions in the estimated effects of parental education on these outcomes reflected the strong effect of exit exam scores on high school enrollment—that is, the strength of path *b* in Figure 1. In both the full and adoptive samples, a one *SD* increase in exit exam score predicted a roughly 20 percentage points increased likelihood of high school enrollment.

Importantly, the absence of any nongenetic contribution of parental attainment specific to enrollment is less conclusively demonstrated than was the absence of a similarly specific contribution to child attainment—recall that among adopted

Table 2
Predicting High School Completion and Enrollment With Parental Education

	High school completion		High school enrollment			
Dependent variable	Unconditional		Unconditional		Conditional on exit exam	
Model identifier	(a)	(b)	(c)	(d)	(e)	(f)
Population sample number	Full	Adoptees	Full	Adoptees	Full	Adoptees
	[1a]	[1b]	[2a]	[2b]	[2a]	[2b]
Parental education	0.166	0.029	0.11	0.022	0.031	0.008
	[0.163; 0.168]	[0.010; 0.048]	[0.108; 0.113]	[0.009; 0.036]	[0.029; 0.033]	[−0.003; 0.019]
Boy	−0.152	−0.136	−0.119	−0.091	−0.074	−0.04
	[−0.156; −0.148]	[−0.168; −0.105]	[−0.123; −0.115]	[−0.118; −0.064]	[−0.076; −0.071]	[−0.061; −0.018]
Exit exam scores					0.199	0.239
					[0.198; 0.201]	[0.229; 0.249]
N	412,295	3,297	465,358	3,505	465,358	3,505

Note. Marginal effects from logit estimations on either full populations (samples *N*a) or the corresponding sub-sample of adoptees (samples *N*b). "Unconditional" results do not condition on the prior educational stage. Exit exam is an average of scores on eight exams taken in ninth grade. Parental education is measured in years and averaged between parents. Both exit exam and parental education are then standardized ($M = 0$, $SD = 1$). Boy is a binary indicator (girls = 0). The results listed are marginal effects of individually increasing the continuous variables by one standard deviation or changing gender from girl to boy, while holding all other variables fixed at their median values. 95% confidence intervals in brackets. Constant included in regression but omitted from table.

enrollees, completers had *lower* parental education than noncompleters. In the present case, although the conditional regression result was nonsignificant, it is worth some additional consideration. We used a structural equation model to parallel the regressions (i.e., where both parental attainment and exit exams predicted enrollment), with paths from parental attainment to both child enrollment and exit exams. Results from this model largely fit with the regression results: The path from parental education to enrollment was not significant for adoptees, and dropping the path provided an improved fit according to BIC. However, a lower Akaike information criterion (AIC) value was obtained by retaining the path, rendering a somewhat split verdict on whether any nongenetic effects of parental education specifically affect enrollment.

Two conclusions are less equivocal: The association between parental education and child enrollment appears to predominantly reflect genes shared between the parent and child, and parental education's nongenetic association with child enrollment is predominantly accounted for by earlier stages in the child's educational development. We therefore progress further back in that development to search for where these nongenetic effects are first introduced.

Academic Performance

As with educational enrollment and attainment, academic performance was substantially familial. For the most comprehensive measure of academic performance (the 9th grade exit exams), we observed sibling correlations of .50 ([.50, .51], 102,081 sibling pairs) among nontwin full siblings from the relevant full sample (2a). The sibling correlation of .24 ([.16; .32], 534 sibling pairs) in the corresponding adoptee sample (2b) indicates the familial influences were roughly evenly split between genetic and shared environmental sources.

Figure 3A and 3B show that, as with the previous characteristics, there was a substantial link between parental attainment and child academic performance in the relevant full sample, whether that was assessed using the comprehensive exit exams ($\beta = .44$ [.44, .44]; Sample 2a) or with the multiyear composite for the biannual reading tests ($\beta = .34$ [.34, .34]; Sample 4a). (Full numerical results presented in Table 3.) It also shows that these links were substantially attenuated in the adoptee samples: The corresponding values were betas of .05 [.02, .09] (Sample 2b) and .06 [.02, .10] (Sample 4b). Academic performance thus resembles the previously discussed educational characteristics (enrollment in and completion of advanced education): Performance is substantially influenced by both genes and environment, and it associates with parental attainment primarily, but not exclusively, through genetic mechanisms.

Unlike the other educational characteristics, however, we can provide some fine-grained exploration of development within this characteristic, due to the availability of language test scores for individual grade levels. A first result of interest is that there was significant stability in performance on these exams across grades: In analyses on a restricted version of Sample 3a, which required participants to have data on all four exam years ($N = 75{,}989$), the correlation between performance in Grades 2 and 4 was .67, with somewhat higher correlations (.73 and .72) observed for Grades 4/6 and 6/8, respectively.

A second result of interest is that parental attainment was predictive of child academic performance even in the earliest assessment (Grade 2), not only among the full sample ($\beta = .31$ [.31, .31]) but also among adoptees ($\beta = .05$ [.01, .10]). A third result of interest is that although parental attainment retained some incremental predictive power after controlling for prior performance in the full sample (e.g., $\beta = .13$ [.13, .14] when predicting Grade 4 performance), among adoptees it did not ($\beta = .02$ [−.02, .05]). Results using the regression framework employed thus far are presented in Table 4, but we also simultaneously analyzed performance at all four assessments (Grades 2, 4, 6, and 8) using the structural equation model illustrated in Figure 4. The results confirm the original conclusion: Whereas among the full population the best fitting model preserved

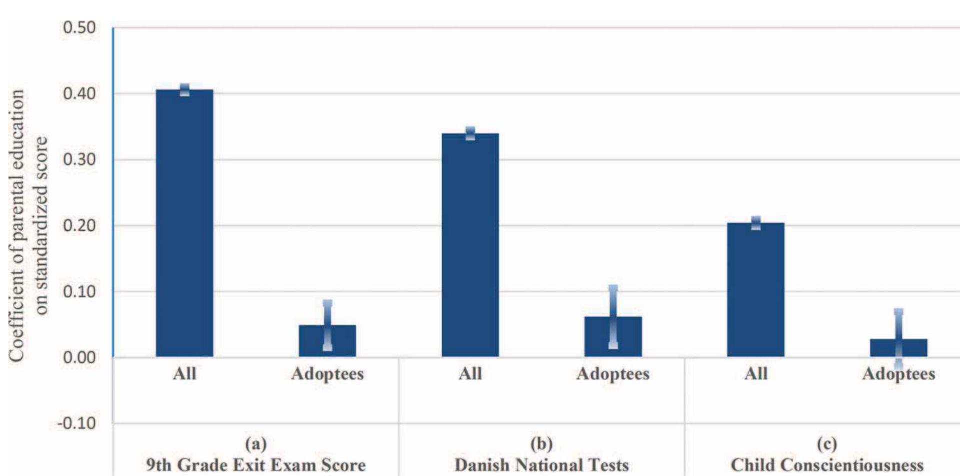

Figure 3. Coefficients from regression of child academic performance and Conscientiousness on parental education (all standardized continuous variables). The estimates shown are regression coefficients of standardized parental education on standardized scores; full numerical results in Table 3. The 95% confidence intervals are indicated as whiskers. See the online article for the color version of this figure.

Table 3
Predicting Academic Performance and Conscientiousness With Parental Education

Dependent variable	Ninth-grade exit exam 2007–2014		Danish national test 2014–2017				Child conscientiousness	
	Unconditional		Unconditional		Conditional on child conscientiousness		Unconditional	
Model identifier	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Population sample number	Full [2a]	Adoptees [2b]	Full [4a]	Adoptees [4b]	Full [4a]	Adoptees [4b]	Full [4a]	Adoptees [4b]
Parental education	0.406 [0.401; 0.411]	0.049 [0.015; 0.083]	0.34 [0.334; 0.345]	0.062 [0.019; 0.106]	0.286 [0.281; 0.292]	0.052 [0.012; 0.092]	0.204 [0.198; 0.209]	0.028 [−0.014; 0.070]
Boy	−0.234 [−0.241; −0.226]	−0.227 [−0.292; −0.162]	−0.208 [−0.215; −0.200]	−0.326 [−0.400; −0.252]	−0.218 [−0.225; −0.211]	−0.29 [−0.361; −0.220]	0.035 [0.028; 0.042]	−0.129 [−0.199; −0.060]
Child C					0.264 [0.261; 0.268]	0.316 [0.279; 0.353]		
N	465,358	3,505	392,163	2,799	392,163	2,799	405,762	2,952

Note. Coefficients from an Ordinary Least Squares regression using either full populations (samples *N*a) or the corresponding subsample of adoptees (samples *N*b). "Unconditional" results do not condition on the prior educational stage. Exit exam is an average of scores on eight exams taken in ninth grade. Danish national test is a multiyear composite score of reading ability. Parental education is measured in years and averaged between parents. "Child C" is child conscientiousness. All variables except gender are standardized ($M = 0$, $SD = 1$). Boy is a binary indicator (girls = 0). 95% confidence intervals in brackets. Constant included in regression but omitted from table.

pathways between parental education and performance on each exam, among adoptees the model with the lowest AIC and BIC dropped all paths except that to Grade 2 performance. This could be interpreted as indicating that any nongenetically mediated associations between parental attainment and child academic performance were already complete in the early years of the child's schooling.

We next evaluate one last way in which the nongenetic effects of parental education might be attributable to influences earlier in the child's development. Unfortunately, the available data has substantial limits for addressing this particular question: Our assessment of educationally relevant psychological characteristics (which should influence academic performance) is obviously not comprehensive, given that we lack any information concerning the child's IQ and instead have only personality data available. Regression results from Sample 4a (presented in Table 2) show that conscientiousness was, in fact, a reasonably potent predictor of academic performance (betas of .26 [.26, .27] and .32 [.28, .35] in the full and adoptive samples, respectively). However, controlling for conscientiousness in panel (b) of Table 3 only reduced the effect of parental attainment on child academic performance by roughly 16% in both the full (3a) and adoptee (3b) samples, compared to dramatically larger reductions for the previously discussed comparable analyses on attainment and enrollment in advanced education. Parental attainment thus remained a significant predictor of child academic performance for both the full (β = .29 [.28, .29]) and adoptee (β = .05 [.01, .09]) samples. Given this, both paths g_{ii} and ng_{ii} from Figure 1 are retained.

Academically Relevant Psychological Characteristics

Sibling correlations for conscientiousness were, relative to the other traits discussed, comparatively modest, consistent with previous research (Matteson, McGue, & Iacono, 2013). Among nontwin full siblings from the relevant full sample (4a), sibling correlations were only .22 ([.22, .23], N = 90,701). Adoptive sibling correlations (in sample 4b) were smaller still (r = .11 [.01, .20], N = 517). However, as shown in Figure 3C (numerical results in Table 3), whereas parental attainment significantly predicted child conscientiousness (β = .20 [.20, .21]) in the full sample, this association was reduced to statistical insignificance among adoptees (β = .03 [−.01, .07]). Accordingly, although there appears to be both a genetic and shared environmental component for conscientiousness in the present sample, parental education's associations with this characteristic were exclusively genetic (path g_I in Figure 1) rather than environmental (path ng_I) in nature.

Supplementary Analyses

Because of the small but statistically significant (negative) association between parental attainment and the HDI score for the child's country of origin, we performed supplementary versions of all regression analyses described above. In each analysis in Supplemental Table S6 in the online supplemental materials, an interaction between parental attainment and HDI was not significant, indicating that parental attainment had consistent relationships with child educational characteristics across different levels of development in the child's country of origin. The small link between parental attainment and (young) child age at adoption also required investigating, given the possibility that the elevated educational outcomes exhibited by children adopted by educated parents reflected this extra time in the adoptive home. This was not the case, as indicated by supplementary versions of all analyses that included an interaction term for child age at adoption and parental education in Supplemental Table S7 in the online supplemental materials.

Intergenerational Modeling Using a Nuclear Twin Family Model

Most of the child educational characteristics considered in this paper do not have data available for the parent generation, preventing us from using any formal model that integrates sibling and parent–child data. One exception concerns high school attainment: Although our analyses to this point have operationalized parental educational attainment as a continuous variable that can more fully capture the existing variation in parental schooling, it is possible to dichotomize parental scores into the same version as used for their children (i.e., high school completion vs. not), so as to enable us to use an adapted version of the Nuclear Twin Family Model (NTFM; Keller et al., 2009; Neale, Walters, Eaves, Maes, & Kendler, 1994). The NTFM is a highly complex model that uses information about how a characteristic (here, high school attainment) covaries between different types of family members to ascertain how much of the variance in that characteristic can be attributed not only to frequently discussed contributors (such as genetics, the family environment, and the unique experiences of the individual) but also to some less commonly considered contributors (such as the sibling environment, also known as horizontal transmission, and the twin environment). Here we focus only on the core results of interest, though for a fuller discussion of the NTFM, see Supplementary Materials S6 in the online supplemental material.[5]

Three results from the model are most noteworthy. First, the model shows genetics to play a smaller role than one would have assumed had one simply applied Falconer's formulas (Falconer, 1960) to the various parent–child resemblances discussed above. A Falconer-based approach (which simply compares parent–child similarities in high school attainment among biological vs. adoptive families) would point to a heritability of .61, which is to say that 61% of the variability in high school completion is attributed to genetic influences. However, the NTFM incorporates information regarding the (very substantial: r = .61 [.60, .61]) correlation between the high school attainment of the mother and father, and as a consequence estimates the heritability to be only .45 [.36, .55].

A second result reflects the fact that adoptive sibling similarity for attainment was considerably more pronounced than was similarity between adoptive parents and children. As a consequence, the sibling environment (.24 [.22, .25]) is estimated by the model to account for the overwhelming majority of the influences from the family environment. A related observation with implications to be discussed below is that none of this could be attributed to twin-specific environmental effects (−.03 [−.06, .00]).

A third noteworthy result is that despite the dominance of the sibling environment, dropping the maternal and paternal transmission pathways led to a decrease of model fit ($\chi^2(2) = 36.87$, $p = 9.84 \times 10^{-9}$), consistent with the significant regression result reported above based on the more fine-grained education measure. However, each path was individually not statistically significant, and the maternal and paternal paths were highly comparable in magnitude (maternal: .02 [−.02, .06]; paternal: .03 [−.01, .07]).

Discussion

The present research points to two primary trends. First, although in the full population we found that more educated parents have children who thrive at every stage of educational development, this relationship was overwhelmingly dependent on the nature of the family: When the parents and children did not share genes, the children reared by more highly educated (adoptive) parents looked largely, though not entirely, the same as those reared by less educated (adoptive) parents on any of the educational characteristics assessed here.

Second, the nongenetic effects responsible for the relationship of parental attainment with child educational characteristics appear to have occurred early in the child's educational development. That is, rather than specifically influencing the child's enrollment in or completion of advanced education, our results are more consistent with parental attainment instead having influenced these characteristics by first affecting child academic performance and doing so at a very young age. The earliest nongenetic effects we identify occur at Grade 2 already. However, the early nongenetic effects did not include effects on conscientiousness: Although parental education was nontrivially associated with child conscientiousness in the general population, the absence of any such link among adoptive families suggests the relationship exclusively reflects shared genes.

Evaluating Alternative Explanations

There are well-known assumptions and limitations to the use of adoptee samples (Jaffee, Price, & Reyes, 2013). For instance, adults applying to adopt a child in Denmark must fulfill a number of requirements, which include an assessment of their physical and psychological conditions, their residence, how long couples have lived together, their financial situation and their criminal records. This selection procedure is reflected in our results showing that adoptive parents are less likely to be divorced, to have been to prison, or to have had psychiatric diagnoses. However, we can address or examine many of these issues of selection in the present study. From these examinations, we saw no particular cause for concern. For example, it is true that adoptive parents were moderately more educated than the full population, but because the variance in years of education completed was only modestly (6.5%) smaller among adoptive parents than the full population of parents, there seems little reason to attribute the failure of adoptive

[5] A full discussion of the NTFM and its results requires substantial space and is most relevant to a subset of the present study's target readership. Given the supplementary nature of these analyses, we leave the detailed explanation of the model and a full presentation of its results for the noted online supplementary materials. Note that because zygosity information is not available to us we cannot make effective use of same-sex twin pairs, but results presented here are based on a model that does include opposite sex twin-pairs—see Supplementary Materials S6 in the online supplemental material for detailed further discussion of same-sex twin pairs.

Table 4
Predicting Academic Performance Throughout Development

	(a)					
	Grade 2 DNT				Grade 4 DNT	
Dependent variable	Unconditional		Unconditional		Cond. on Grade 2 DNT	
Model identifier	(a)	(b)	(c)	(d)	(e)	(f)
Sample number	Full	Adoptees	Full	Adoptees	Full	Adoptees
Parent education	0.308	0.0543	0.331	0.0554	0.134	0.0183
	[0.303, 0.314]	[0.005, 0.104]	[0.326, 0.336]	[0.005, 0.106]	[0.130, 0.138]	[−0.017, 0.054]
Boy	−0.238	−0.287	−0.193	−0.326	−0.0409	−0.130
	[−0.245, −0.230]	[−0.374, −0.200]	[−0.200, −0.185]	[−0.414, −0.238]	[−0.046, −0.035]	[−0.195, −0.06]
Grade 2 DNT					0.639	0.684
					[0.634, 0.643]	[0.641, 0.727]
Grade 4 DNT						
Grade 6 DNT						
N	300,298	2,049	300,298	2,049	300,298	2,049

Note. Results from an ordinary least squares regression in sample collection 3. "Unconditional" results do not condition on the prior educational stage. Danish national test (DNT) scores are composite scores from computerized adaptive tests in three areas of reading ability, taken in Grades 2, 4, 6, and 8. Parental education is measured in years and averaged between parents before it and all variables except gender are standardized ($M = 0$, $SD = 1$). Boy is a binary indicator of the gender of the child. 95% confidence intervals are given in square brackets. Constant included in regression but omitted from table. Cond. = conditional.

parental attainment to predict educational characteristics of the child to insufficient variation in that education. Similarly, although adoptees generally fared somewhat less well than average, the variation among adoptees was generally highly comparable to the broader population, such that little of the difference in parent–child similarity between adoptees and the general population is likely to reflect restricted variance among adoptive families.

We also see no reason to attribute these results to the age at which the children were adopted. First, supplementary moderation analyses did not suggest effects were stronger among those adopted earlier (see Supplemental Table S7 in the online supplemental materials). Second, if adoptive parental education failed to predict child characteristics simply because the adoptive children had been insufficiently exposed to the environment provided by their adoptive parents, then effects of adoptive parental education might be most expected at later ages, by which time the children have spent more time in their adoptive environment. That contrasts with our observation that the shared environmental effects of

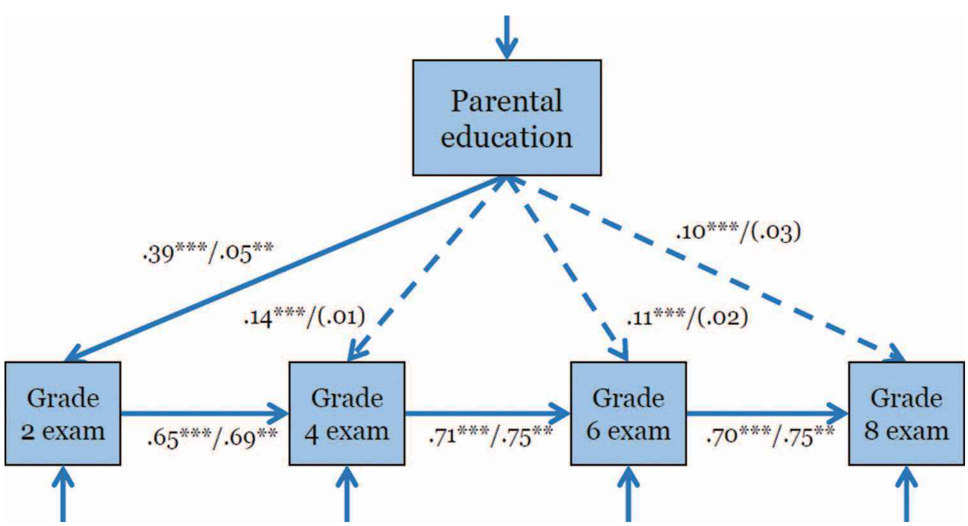

Figure 4. Results from a path model between parental educational attainment and child's performance on the Danish national tests. Results before the slash are coefficients from the full population; those after are from adoptees. Solid lines represent paths that are retained in the best fitting models for both populations. Dotted lines represent paths for which model fit was improved when dropped among adoptees. No path could be dropped for the full sample without worsening model fit. Because the adoptee result for each dotted-line path in the best fitting model is always .00, for these paths we report in parentheses the adoptee result from the full model with no paths dropped. * $p < .05$. ** $p < .01$. *** $p < .001$. See the online article for the color version of this figure.

Table 4 (*continued*)

(b)							
Grade 6 DNT				Grade 8 DNT			
Unconditional		Cond. on Grade 4 DNT		Unconditional		Cond. on Grade 6 DNT	
(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)
Full	Adoptees	Full	Adoptees	Full	Adoptees	Full	Adoptees
0.333	0.0483	0.104	0.0232	0.315	0.0329	0.0893	0.0231
[0.327, 0.339]	[0.003, 0.094]	[0.101, 0.108]	[−0.007, 0.053]	[0.310, 0.320]	[−0.014, 0.080]	[0.086, 0.093]	[−0.008, 0.054]
−0.197	−0.276	−0.0769	−0.0585	−0.157	−0.188	−0.0438	−0.0581
[−0.205, −0.188]	[−0.356, −0.195]	[−0.082, −0.072]	[−0.112, −0.005]	[−0.165, −0.149]	[−0.272, −0.104]	[−0.049, −0.038]	[−0.114, −0.003]
		0.708	0.739				
		[0.703, 0.713]	[0.703, 0.774]				
						0.704	0.747
						[0.699, 0.709]	[0.705, 0.788]
297,138	2,293	297,138	2,293	274,098	2,170	274,098	2,170

parental attainment were "baked in" to the earlier stages. However, our study can of course not rule out the possibility that parent–child similarity in educational characteristics among the full population partially represents the effects of behaviors of the parents very early in the child's life (such as in the first months or even in utero, before the time when meaningful numbers of our adoptee samples was living in their adoptive homes). This is important for recognizing that, to the extent that these very early environmental experiences are highly important, our study may underestimate the degree to which parental education can have nongenetic linkages with a child's educational development. Still, this limitation seems primarily relevant to the question of the magnitude of the nongenetic effect of parental education on child education, and not the distinct issue of the timing of those effects. It seems unlikely (though not impossible) that prenatal or peri-natal experiences have *specific* effects on later stages in educational development rather than having early and persisting effects throughout development. Given this, our conclusion that nongenetic transmission of education appears to occur via effects early in the child's development rather than via specific contributions to later educational stages does not appear to be meaningfully challenged by this limitation of the adoptee study design. Further, the absence of a twin-environment effect in the nuclear twin family model analyzing high school completion is inconsistent with a substantial role for in utero effects for that characteristic, given that, unlike ordinary siblings, twins share the uterine environment.

Another limitation to our study comes from the registry-based nature of the data, which does not contain information on whether adoptive children have postadoption contact with their birth parents. However, the vast majority of nonfamily adoptions were international adoptions, among whom persistent and meaningful postadoption contact is unlikely. Importantly, there were no substantive differences in our results when we limited our analyses to these international adoptees (see results in Supplemental Table S5 in the online supplemental material).[6] We thus see no reason to attribute our results to potential postadoption contact.

Although the registry-based nature of the study provides us with uncommonly complete data, missing data still might have attenuated some parent–child relationships. For example, students do not appear to be missing exit exam data randomly: Supplemental Table S8 in the online supplemental material shows that the parents of children who missed none of the eight exit exams were almost twice as likely to have completed high school as were those who missed any or all exit exams. In addition, students who missed an exit exam performed dramatically worse on any exams they did complete. Thus, students who were not included in exit exam analyses due to missing data appear likely to have represented the lower tail of student academic performance, while their parents represented the lower tail of the parental education distribution. Observed relationships between parental education and child academic performance thus may have been somewhat attenuated.

Missingness also somewhat limits the generalizability of our findings. For example, whereas younger students have parental education data recorded at high rates, 14% of children in the oldest full population sample (1a) were missing parental education data. This missingness was far from random: 94% of these children were classified as immigrants or the descendants of immigrants, such that 59% of all immigrant/descendant children in Sample 1a lacked parental education data. The generalizability of our full sample results to immigrant families thus remains open to further study. Importantly, though, this issue does not appear to affect our core results concerning adoptees: The above-noted infrequency of adoption of immigrant families helps understand why adoptive parents rarely (1.6%) had missing education data.

[6] An additional set of analyses using geographic restrictions—eliminating adoptees from both European countries and former Soviet Republics—are discussed in greater detail in Supplementary Materials S5 in the online supplemental material. Results are not appreciably different from the full sample, but these results are perhaps not readily interpretable, as there are different grounds for expecting both higher and lower adoptive parent–child similarity among the excluded subset.

Power limitations must also be considered for our adoptee findings. Although the contribution of adoptive parents' attainment to child enrollment in advanced education was rendered nonsignificant after conditioning on prior exit exam performance, this result could reflect low power: One fit index (but not another) suggested the best model was one in which adoptive parental education retained a nongenetic effect on enrollment even after considering effects on exit exams. A sample larger than that analysis' 3,505 adoptees may have been able to show less equivocal evidence of time-specific effects.

Generalizability of Adoptee Results

To evaluate the generalizability of our adoptee findings, it is instructive to compare them to those from other cultural contexts as well as those derived from other approaches (e.g., twin studies). Previous research has found that genetic influences on educationally relevant features such as intelligence are suppressed (and shared environmental features enhanced) under deprived socioeconomic conditions (Tucker-Drob & Bates, 2016; Turkheimer, Haley, Waldron, D'Onofrio, & Gottesman, 2003). In northern Europe, comparatively fewer families will find themselves in such deprivation, thanks to the wealth and redistributive policies that are in place. Therefore, in societies such as Denmark's, a comparatively larger role should be observed for genetics and a smaller role by the shared environment. A comparison of twin studies from different contexts supports this expectation (Branigan, McCallum, & Freese, 2013): When compared to results from other countries, there is substantially higher heritability and (with the exception of Norway) lower shared environmentality for educational attainment in Denmark (Rodgers et al., 2008), Finland, Sweden, and Germany.[7]

This context helps to show that the estimated role for the shared environment in the present study (.25 for educational attainment, as indicated by the adoptive sibling correlation) is a plausible result for a Danish study, even if it is smaller than the result derived by averaging all twin studies from around the world (.36; see Branigan et al., 2013). In fact, .25 is precisely the shared environmental estimate also observed by the most relevant Danish twin study (Rodgers et al., 2008). By contrast, the shared environmental estimate of .37 derived from McGue's American adoptive sample (McGue et al., 2017) is a reasonable match to the estimate expected from American twin samples (Branigan et al., 2013). We thus have no clear indication that adoptee samples, especially of the size and completeness of that used here, are particularly prone to understate the importance of the shared environment for these features.

At the same time, the considerations just discussed point to a clear reason to expect that studies from other nations may point to a greater role for the shared environment in educational development. This would be particularly noteworthy if, as a consequence, nongenetic effects of parental education on various child educational characteristics would also be greater than observed here. However, comparing our results to McGue et al. (2017) provides no support for this concern: They found that parental educational attainment predicted adoptive child college completion with an odds ratio of 1.3, whereas in our data the odds ratio of parental educational attainment on high school completion was 1.13. The z-value for a test of these odds ratios being equivalent was 1.3, meaning we cannot reject the null hypothesis that they are equal. Nevertheless, further research in contexts where a greater share of the population faces economic deprivation is clearly merited before the present results are unquestioningly extrapolated to such contexts.

There are other noteworthy parallels between the present results and those obtained from twin studies. Of the educational characteristics we explored, enrollment in advanced education exhibited a comparatively large role for the shared environment, as did a recent U.K. study using the Twins Early Development Study (TEDS) sample to evaluate multiple educational characteristics (Smith-Woolley, Ayorech, Dale, von Stumm, & Plomin, 2018). A previous study on TEDS participants (Shakeshaft et al., 2013) analyzed performance on a set of exams comparable to the Danish exit exams analyzed here, finding a level of similarity among dizygotic twins that was similar to though slightly larger than the sibling similarity coefficients reported here. Conceivably, those slightly larger correlations might simply reflect that the present study's siblings typically took the exams several years apart, unlike the twins studied by Shakeshaft et al. (2013).

Beyond considering how our adoptee results compare to other quantitative genetic studies (whether on twins or other adoptees), we can also evaluate how they compare with molecular genetic work. Just as molecular genetic studies tend to produce lower heritability estimates than do quantitative genetic studies of twins (Rimfeld et al., 2018), studies looking at intergenerational transmission from a molecular perspective suggest that far less of that transmission is genetic than is implied by studies using an adoptee design (e.g., Conley et al., 2015; McGue et al., 2017; and the present work). Unfortunately, the present data does not provide us with the ability to differentiate whether molecular studies are simply underestimating genetic effects (as those favorably inclined to genetic explanations might argue), or whether flaws in the adoptee model (such as omission of prenatal environmental effects) have led to an underestimate of the role of environment and an accompanying inflation in the estimate role of genetics. At the same time, there are important commonalities between some results from molecular studies and those based on the adoption design: Just as our work provides evidence for some degree of educational similarity across generations even in the absence of shared genetics, recent studies of "genetic nurture" show that parental genes related to education can predict child education even when those genes are not transmitted to the child (Kong et al., 2018; Willoughby, McGue, Iacono, Rustichini, & Lee, 2019).

Measuring Attainment With Completion of Academic High School

Our use of the completion of academic high school to represent educational attainment requires discussion of two distinct sets of

[7] This trend was not identified in the meta-analysis (Branigan et al., 2013), reflecting that study's inclusion of a working paper on a segment of the Danish Twin Registry with many young participants. As can be expected, the young age of the participants appears to have markedly suppressed the degree to which educational attainment correlated among family members. A published study on an appropriately-aged segment of the same twin registry (Rodgers et al., 2008) that was not included in the meta-analysis instead shows results that are very much in line with those of other northern European nations.

considerations. The first is the issue of which educational characteristics are most important. The second concerns when parents matter most.

Most literature on educational attainment focuses on completion of college degrees, whereas the present study uses completion of academic high school. As discussed in Supplementary Materials S1 in the online supplemental material, this was necessitated by the young age of those whose adoptee status is recorded in public Danish registries. We argue, however, that while this measure of attainment occurs prior to completion of college, it represents a meaningful and relevant measure of attainment nevertheless. Importantly, in the Danish context academic high school ("gymnasium") plays a very different role than in educational systems such as the United States. Enrolling in high school is not open to all students, instead requiring students to demonstrate significant academic competence. Students with a less academic orientation pursue one of many alternatives with a more vocational angle. The significance of attaining a high school degree is perhaps best indicated by considering its associations with life outcomes. In terms of further education, although only 31% of the Danish population obtains a college degree, fully 62% of those who completed high school will complete college. (Details about this result are provided in Supplementary Materials S2 in the online supplemental material). Economically, completion of both high school and subsequently college seem to be associated with meaningful rewards: A comparison of earnings published by Statistics Denmark (Danmarks Statistik, 2013) notes that men and women with a high school degree earn 21% and 7% more on average than those with compulsory schooling only. Those with a bachelor earn another 18% or 19% more (men/women), and those with a master's/long university degree 48% or 55% more. Accordingly, many of the dynamics that influence college enrollment and completion—whether they be considerations of future earning potential, academic interests, or academic competencies—are highly relevant for high school enrollment and completion in Denmark.

At least one major difference requires further attention, however, and that is the age typical for enrollment and completion for high school versus for college. Previous research has found that the influence of parents and the shared environment changes substantially over the life course, diminishing as the child ages (Bergen et al., 2007). Accordingly, our estimates for the importance of the shared environment and the correlation in educational characteristics between adoptive parents and children might be expected to be overestimated in the present work, relative to analyses of college enrollment and completion. However, the identical estimates for the role of the shared environment in our adoptee study of high school completion and the previously noted Danish twin study of college completion does speak against this possibility.

Conclusion

Using a national, genetically informative sample, our study provides the most thorough exploration ever performed of how parental educational attainment associates with their children's educational development. Both genes and the shared environment influenced each component of the child's educational development, beginning with the child's personality, through the child's academic performance, and into their advanced educational enrollment and attainment. However, our findings were not consistent with parental educational attainment having pronounced nongenetic links with these educational outcomes. Instead, nongenetic effects of parental educational attainment appeared best interpreted as small effects on early academic performance that proceeded to impact later educational outcomes.

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