Child-Driven Parenting: Differential Early Childhood Investment by Offspring Genotype

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Abstract

Socioeconomically advantaged families can draw on greater economic, social and cultural resources to compensate for adverse child development or to reinforce positive child development. Previous research has shown differential parental response by socioeconomic status to children's birth weight, early cognitive ability, and school outcomes – all early life predictors of later socioeconomic success. This study considers an even earlier predictor: children's genotype. The study analyzes (1) whether parents reinforce or compensate for children's genetic propensity towards educational success, and (2) whether reinforcement (or compensation) differs by family socioeconomic status. Using data from the Avon Longitudinal Survey of Parents and Children (N=7,291), we construct polygenic scores for educational attainment and regress these on cognitively stimulating parenting in early childhood. We use a number of modeling strategies to address the concern that child's genotype may be proxying unmeasured parent characteristics. Results show that lower SES parents provide more cognitively stimulating activities during early childhood to children with higher polygenic scores for educational attainment, while higher SES parents do not alter their behavior in response to the revealed genetic predisposition of offspring.

Introduction

There is a growing interest in how children socialize parents. Studies have looked at whether parents' political and religious opinions and behaviors and even parents' likelihood of divorce are affected by the sex of their children (Aksoy, 2017; Conley & McCabe, 2012; Conley & Rauscher, 2013; Hamoudi & Nobles, 2014; B. Lee & Conley, 2016; Owsald & Powdthavee, 2010). While the sex of the firstborn child meets the conditions for a natural experiment, most other child characteristics are dependent on parent characteristics making the causal effects of child characteristics on parents' behavior hard to impossible to detangle. An exception is the genotype of the child which is made up by a random half of the mother's genome and a random half of the father's genome. Conditioning on the parents' genotype, children's genotype provides a natural experiment. Since genetic molecular data are now available in large-scale surveys, this opens up for the examination of whether parents' behavior is affected by children's genetic make-up?

A set of parents' behaviors that is particularly important to children's wellbeing is parenting. Both observational studies and interventions show that parenting practices during early childhood such as shared book reading and play increase children's cognitive skills and later socioeconomic attainment (Attanasio et al., 2014; Fiorini & Keane, 2014; Gertler et al., 2014; Heckman & Mosso, 2014; Hsin & Felfe, 2014). Meanwhile, other research has underlined the importance of persistent parental investment over the childhood for such effects to last (Andrew et al., 2018; Doyle, Harmon, Heckman, Logue, & Moon, 2017). Parenting activities are theorized to increase children's skills directly, as well as their general interest in learning (Feinstein, Duckworth, & Sabates, 2008; Melhuish et al., 2008).

While the focus is often on how parents' socioeconomic resources are related to parenting, child characteristics and behavior may also be an important influence (Feinstein et al., 2008; Melhuish et al., 2008). The literature on within-family inequality speaks to this, finding that parents do indeed treat their children differently (Conley, 2004). During early childhood, sibling differences in birthweight and early cognitive skills lead to differential cognitive stimulation (Aizer & Cunha, 2012; Grätz & Torche, 2016; Hsin, 2012; Restrepo, 2016; for reports of neutrality see Abufhele, Behrman, & Bravo, 2017). The influence of child characteristics on parenting goes beyond allocating resources between siblings: Parents adjust their parenting dynamically in response to children's school performance (Quadlin, 2015), and qualitative studies of shared book reading shows that children very much drive and shape this parenting practice (Hall, Levy, & Preece, 2018; Luo & Tamis-LeMonda, 2017). Together, these studies show that children play a crucial role in determining the amount and type of cognitively stimulating parenting they receive.

While birth weight, early cognitive skills and school performance are predictors of later educational attainment, an even earlier predictor would be children's genotype. Moreover, this predictor is randomly assigned (conditional on parental genotype) at conception, not readily observable (as compared to birth weight) and not subject to reverse causation (as early cognitive ability and school performance might be). Genetic variation is related to educational attainment (Branigan, McCallum, & Freese, 2013; Conley et al., 2015), but the mechanisms are unclear. One possibility is that genetic effects are mediated by the social environment by eliciting certain responses from for example parents (Jencks, 1980). Indeed, a recent study shows that parents may reinforce children's genetic propensities towards educational success by providing a better home learning environment (Wertz et al., 2018). Wertz and colleagues study parenting during middle childhood (age 5-12 years), but since socioeconomic and genetic differences in cognitive skills show up well before school age (Belsky et al., 2016; Feinstein, 2003), and learning during early childhood is crucial for later achievement (Cunha, Heckman, Lochner, & Masterov, 2006), it begs the question of whether children's genetic propensity towards educational success affects parenting during early childhood. Further, the above study is limited in its ability to draw causal conclusions due to the potential endogeneity of the key measure of child endowment since both parents' genotypes are not controlled and—while maternal genotype is held constant—there is no strategy to deal with potential confounding by father's genotype or unmeasured aspects of maternal genetics or cultural capital (which may be correlated with child genotype due to population stratification).

Meanwhile, it has been argued that socioeconomically advantaged families can draw on more economic, social, and cultural resources to compensate for negative child development or reinforce positive child development (Conley, 2004). For example, early-pregnancy stress exposure has a strong negative influence on children's cognitive skills among disadvantage families, but no association with children's cognitive skills in middle-class families (Torche, 2018). Similarly, being the youngest in the classroom places children of lower educated parents at higher risk of grade repetition than children of higher educated parents (Bernardi, 2014). Within families, some studies show that advantaged parents provide more cognitively stimulating parenting to siblings with low birth weight, while disadvantaged families reinforce sibling difference (e.g., Aizer and Cunha 2012; Hsin 2012; Restrepo 2016). However, a lack of variation across socioeconomic status in parental responses to sibling difference in birthweight has also been reported (Abufhele, Berhman, and Bravo 2017), and the pattern is reversed in terms of early cognitive skills, where advantaged parents reinforce sibling differences and disadvantaged parents do not differentiate (Grätz and Torche 2016). We have yet to learn whether the parenting that children's genetic make-up elicits depend on the socioeconomic status of the family.

While sociology has theorized genetic effects to operate via social mechanisms a long time ago (Jencks 1980), up until recently this hypothesis was very hard to test. Now molecular genetic data are available in large scale surveys making it possible to directly measure genetic make-up (or genotype). Recent studies show that multiple genes indexed via single nucleotide polymorphisms (SNPs) across the genome are related to educational attainment (Lee et al., 2018; Okbay et al., 2016; Rietveld et al., 2014, 2013). Results from these studies can be used to construct a measure of genetic propensity for educational attainment, a so-called polygenic score. Polygenic scores for educational attainment predict cognitive and socio-emotional skills in childhood, school performance in adolescence and young adulthood, and educational attainment in adulthood (Belsky et al., 2016; Conley et al., 2015; Liu, 2018; Ward et al., 2014; Zhu, Chen, Moyzis, Dong, & Lin, 2015).

This study analyzes whether children with higher polygenic scores for educational attainment receive more (or less) cognitively stimulating activities in early childhood. Further, we will examine whether such reinforcing (or, by contrast, compensating) parental investment strategies vary by family socioeconomic status. We use data from the Avon Longitudinal Study of Children and Parents (ALSPAC). This data set is ideal, since it provides genotype data on children, mothers, and fathers, and measures of cognitively stimulating parenting from infancy through preschool age.

To preview our results: We find that overall parents provide more cognitively stimulating parenting to children with higher polygenic scores, but that this effect is concentrated among lower SES families, no matter how we measure that. Our findings are robust to a variety of ways to control for the potential endogeneity of child PGS to overall parenting style. These findings suggest that genetic effects on educational attainment partly operate by eliciting favorable parenting. The elicited response is, however, contingent on socioeconomic circumstances.

Data

We use data from the Avon Longitudinal Study of Children and Parents (ALSPAC). ALSPAC is a birth-cohort study that sampled 14,541 pregnancies with expected delivery dates between April 1991 and December 1992 in the former Avon County around Bristol, United Kingdom. Among these pregnancies, 13,988 children were alive at age one. ALSPAC is ideal for the purpose of our study because a sizable subsample of the children, mothers, and fathers are genotyped, and because ALSPAC contains information on parenting and socioeconomic status throughout early childhood. As we will explain in the Analytical Strategy section below, there is a trade-off between a research design controlling thoroughly for all confounders and a sample size providing sufficient statistical power. To balance this trade-off, we define three samples: Sample 1 conditions on parenting measures at age six months and consists of 7,291 children; Sample 2 conditions on parenting measures at age six months and mother's genotype and consists of 5,714 children; and Sample 3 conditions on parenting measures, mother's genotype and father's genotype and consists of 1,402 children. Table 1 displays mean and standard deviations of the involved variables for each sample.

Outcome: Parenting

Our outcome variable is parenting reported by the mother when the child was 18, 24, 38, and 57 months old. This age range captures the early childhood before children start school, and parents have yet to receive evaluations of their children's academic abilities. At these ages ALSPAC asked the mother how frequent she did a series of activities with the child (reading stories, singing songs, cuddling, etc.). Table 2 shows the items for each survey wave. To obtain a measure of parenting with the least possible amount of measurement error, we combine all available items from all available waves. We first create sum scores within each wave, standardize the sum scores within each wave, and then calculate an average of the standardized sum scores. Finally, we standardize this variable to have a mean of zero and a standard deviation of one. However, analyzing each wave separately reveals the same pattern of results (results available upon request).

Predictor: The Polygenic Score for Educational Attainment

Our variable of interest is the polygenic score (PGS) for educational attainment. PGS is calculated as a weighted sum score:

$$PGS_i = \sum_{j=1}^{J} b_j G_{ij}$$

where b_j is the association between SNP *j* and educational attainment, G_{ij} is the number of alleles on SNP *j* possessed by individual *i*. We use b_j weights and SNPs from the most recent GWAS on educational attainment (J. J. Lee et al., 2018). Following the recommendations by

Ware and colleagues (2017), we do not prune SNPs in linkage disequilibrium. The mean and the standard deviation of the raw score for children, mothers, and father are displayed in Table 1. For the purpose of regression analysis, we standardize the education PGS to have mean zero and standard deviation 1.

Moderators: Parental Socioeconomic Resources

We use dichotomized indicators for parental socioeconomic status when we analyze whether the effect of the education PGS of children on parenting varies across socioeconomic status. For education, we use an indicator for either parent having an A level or a university degree. For occupational class, we use an indicator of either parent belonging to class I or II. For income, we use an indicator for reporting a weekly family take-home income above 400 UK pound when the child was either 33 months or 47 months old.

Control variables

Education. Mother's and father's education are measured indicator variables for (1) certificate of secondary education or vocational, (2) O level, (3) A level, and (4) university degree. For each parent, we also include an indicator for missing information on education.

Occupational class. Mother's and father's occupational class is measured as (1) V - unskilled, (2) IV - semi-skilled, (3) III - manual, (4) III - non-manual, (5) II - managerial or technical, (6) I - professional. For fathers, we use their own report if available, and the mother's report when the father's own report is missing. For each parent, we also include an indicator for missing information on occupation.

Family income. Mothers were asked to report the family's weekly take-home income on a five-point ordinal scale when the child was 33 and 47 months old. In order to get a robust measure of household income, we combine these two variables into a mean of the standardized items. We standardize this combine household income variable to have mean zero and standard deviation one. The Cronbach's alpha is 88 %.

Parenting at age 6 months. We use a sum score of parenting at age six months as a control variable (see items in Table 2). Net of socioeconomic resources, we expect that parenting at age six months captures parents' propensity towards providing a high level of cognitively stimulation, since the child at this developmental stage has limited agency. This variable is also standardized to have mean zero and standard deviation one. This variable is intended to capture baseline parenting practices and level of involvement in order to have the influence of the child's PGS not reflect its correlation with mother's default parenting practices through the mechanism of shared genetics.

Principal Components of SNP Variation. To account for population stratification in the genetic variation, we control for the first 20 principal components (PCs) of the variation in the SNPs. Since the participants in ALSPAC were recruited from a limited geographical area it is likely that there are unrecorded family ties. These family ties might distort the principal component analysis. For this reason, we follow the procedure used by The UK Biobank (Bycroft et al., 2018) and identify a set of unrelated individuals among the children and mothers, from whom we calculate the PCs. We estimated the kinship relations using the software KING, and used Igraph in R to find a set of unrelated individuals. For this sample of unrelated individuals, we LD pruned the SNPs and calculated the top 8 PCs using PLINK2.0. Based on this first principal component analysis, we selected a set of SNPs that contributed very little to the first three PCs. Using this set of SNPs, we re-estimated the kinship and once again found a set of unrelated individuals. We LD pruned the original set of SNPs for this unrelated sample, and calculated the 20 PCs. Finally, we projected the full sample on to the PCs. Using PC 1 and PC 2 we detected 12 outliers. We removed the 12 outliers from the second sample of unrelated individuals, LD pruned the original set of SNPs for this sample, recalculated the top 20 PCs, and projected them on to the rest of the sample. We use this final set of 20 PCS as control variables.

Analytical Strategy

The purpose of the analysis is to estimate the effect of genetic propensity towards educational success on cognitively stimulating parenting and whether this effect varies across socioeconomic status. To that end we employ four model specifications. In the first step of the analysis we use Sample 1 and regress parenting on the child's education PGS and control variables in the following fashion:

$$Parenting_i = \alpha_0 + \alpha_1 PGS_i + \alpha_2 Parenting\_6m_i + \alpha_3 Sex_i + \boldsymbol{\alpha_4 SES_i} + \boldsymbol{\alpha_5 PC_i} + \varepsilon_i \quad (1)$$

For the i^{th} child, $Parenting\_6m_i$ is parenting by the mother at age 6 months, Sex_i is the sex of the child, $\boldsymbol{SES_i}$ is a vector of mother's education, father's education, household income, and social class, and $\boldsymbol{PC_i}$ is a vector of the first 20 principal components of SNP variation. Sample 1 is the largest possible sample with available child genotype and parenting (N=7,275). Using this sample, we benefit from a high statistical power, but are limited to non-genetic control variables. We make sure to control for the social pathways through which parents' genotypes potentially affect parenting: the propensity towards providing cognitive stimulation, and parental socioeconomic status. We further control for the sex of the child and population stratification. Assuming that this set of control variables captures the relevant confounders, α_1 is the estimated effect of the child's genetic propensity towards educational success on the amount of cognitively stimulating parenting the child receives.

In the next step of the analysis, we add an additional control variable: the education PGS of the mother. This allows us to control directly for confounding by the mother's genetic propensity towards educational success induced in the association between the child's education PGS and parenting by way of the 50 % shared genes between offspring and parents. To control for the influence of the father's genotype on the child's genotype and via assortative mating on the parenting by mother, we control for the father's education and social class. Hence, we specify the following model:

$$Parenting_i = \beta_0 + \beta_1 PGS_i + \beta_2 Parenting\_6m_i + \beta_3 Sex_i + \beta_4 Mother\_PGS_i + \boldsymbol{\beta_5 Father\_SES_i} + \boldsymbol{\beta_6 PC_i} + \nu_i \quad (2)$$

where PGS_i is the education PGS of the child, $Parenting\_6m_i$ is parenting by the mother at age 6, Sex_i is the sex of the child, $Mother\_PGS_i$ is the education PGS of the mother, $\boldsymbol{Father\_SES_i}$ is a vector of variables for father's education and social class, and $\boldsymbol{PC_i}$ are the first 20 principal components of SNP variation. Assuming that we have controlled for all relevant confounders, β_1 captures the effect of genetic propensity towards educational success on parenting. We estimate this model on Sample 2, our second largest sample (N=5,707). The combination of this model specification and sample size strikes the right balance between statistical power and rigorous research design, and is hence our preferred model

The ideal research design in terms preventing confounding (omitted variable bias), is to control for the education PGS of both parents. Half of the genetic variants stems from the mother and the other half from the father. This means that conditioning on both parents' educational PGS renders the variation in the education PGS of child exogenous. We explore this research design in the third step of the analysis and specify the following model:

$$Parenting_i = \gamma_0 + \gamma_1 PGS_i + \gamma_2 Parenting\_6m_i + \gamma_3 Sex_i + \gamma_4 Mother\_PGS_i + \gamma_5 Father\_PGS_i + \boldsymbol{\gamma_6 PC}_i + \mu_i \quad (3)$$

where PGS_i is the education PGS of the child, $Parenting\_6m_i$ is parenting by the mother at age 6, Sex_i is the sex of the child, $Mother\_PGS_i$ is the education PGS of the mother, $ather\_PGS_i$ is the education PGS of the father, and $\boldsymbol{PC}_i$ are the first 20 principal components of SNP variation. γ_1 captures the effect of genetic propensity towards educational success on parenting. This model specification is possible with Sample 3. However, Sample 3 is our smallest sample (N=1,402), which implies a low statistical power. We only estimate as a tentative test of whether the direction and magnitude of the coefficient is the same.

In the final step of our analysis we examine whether the effect of genetic propensity towards educational success on cognitively stimulating parenting varies across socioeconomic status. In order to do so, we specify a model with interaction terms between the education PGS of the child and parental education, parental income, and parental social class:

$$Parenting_i = \delta_0 + \delta_1 PGS_i + \delta_2 SES_i + \delta_3 PGS_i \times SES_i + \delta_4 Parenting\_6m_i + \delta_5 Sex_i + \boldsymbol{\delta_6 PC_i} + \omega_i \quad (4)$$

where PGS_i is the education PGS of the child, $Parenting\_6m_i$ is parenting by the mother at age six months, SES_i is either a dummy for high parental education, parental income, or parental social class, Sex_i is the sex of the child, and $\boldsymbol{PC_i}$ are the first 20 principal components of SNP variation. We estimate the three type of socioeconomic interactions in separate models. To obtain the highest power possible, we estimate these models on Sample 1, but also show results from Sample 2 and Sample 3. δ_3 captures variation across socioeconomic status in parenting response to children's genetic make-up. If δ_3 is positive, parents with high socioeconomic status reinforce their children's genetic propensity towards educational success to a greater extent as compared to parents with low socioeconomic status. If δ_3 is negative, parents with low socioeconomic status reinforce children with greater propensity towards educational success compared to parents with high socioeconomic status.

Results

Since our measure of genetic propensity towards educational success is the education polygenic score from a recent GWAS (J. J. Lee et al., 2018), we begin this section by showing that the polygenic score for educational attainment predicts adult educational attainment for the parental generation in ALSPAC. We then move on to show that our measure of mothers' propensity towards high parental investment—parenting during infancy—is not affected by children's education polygenic scores. With these two findings in place, we progress to address our research questions: (1) does children's genetic propensity towards educational success predict parenting during toddlerhood and the preschool years, and (2) does this association differ by socioeconomic status.

The Association between the Educational PGS and Adult Educational Attainment in ALSPAC

Since the education polygenic score based on the most recent GWAS (Lee et al. 2018), has not yet been show to predict educational attainment in the ALSPAC sample, we begin by documenting the score's relationship to adult educational attainment. We regress mother's educational attainment on the mother's education polygenic score controlling for the first 20 principal components of SNP variation (N=7,620). For this purpose, we measure mother's educational attainment as an ordinal variable with 5 values: (1) CES, (2) Vocational education, (3) O level, (4) A level, (5) Degree. The results are displayed in Table A1 in the appendix. One standard deviation increase in the mother's education polygenic score is associated with 0.47 unit (se=0.013, p-value=0.000) increase in mother's educational attainment. The incremental R^2 for the education polygenic score is 0.14.

Children's Education Polygenic Score and Parenting during Infancy

In all of our models we control for the mother's parenting at age six months as a measure of the mother's propensity towards high parental investment. To assess whether this measure is not driven by the child's genetic propensity towards educational success, but solely by the mother, who shares the child's genes, we regress parenting at age 6 months on the child's education polygenic score. Figure 1 shows the coefficients from our three samples (the full regression results are displayed in Table A2 in the appendix). The models are specified similarly to the models in the main analysis: In addition to the child's sex and first 20 principal components of

SNP variation, in Sample 1 we control for mother's and father's education, occupation, and income; in Sample 2 we control for mother's education polygenic score, and father's education and occupation; and in Sample 3 we control for the mother's and father's polygenic score. None of the estimates are statistically significantly different from zero, and substantially quite close to zero (Sample 1: -.008, se=0.012; Sample 2: -0.016, se=0.016; Sample 3: 0.012, se=0.036). Hence, we conclude that parenting during infancy is driven by the mother's propensity towards high parental investment and not by the child's genetic make-up. The controls for parenting at age six months are particularly reassuring in this regard.

Children's Education Polygenic Score and Parenting during Toddlerhood and Preschool Years

We now turn to our first research question of whether parents' reinforce or compensate children's genetic propensity towards educational success via cognitively stimulating parenting during early childhood. We regress parenting at the age of 18-57 months on child's education polygenic score.

Figure 2 shows the coefficients with 95% confidence intervals (the full regression results are display in Table A3 in the appendix).For each sample we show the results from a model that only controls for child's sex and the first 20 principal components of SNP variation (Model1, Model 3, and Model 5 in Figure 2), and from a model controlling for pathways through which parents' genotypes potentially affect parenting (Model 2, Model 4, and Model 6 in Figure 2).

In Sample 1, one standard deviation increase in child's education polygenic score is associated with 0.081*** (se=0.011) standard deviation increase in parenting (Model 1). Once we add mother's and father's education, occupation, and income, the coefficients drop to

0.032** (se=0.010) (Model 2). In Model 2, the post-hoc statistical power for the child's polygenic score is 78 %.

A very similar pattern appears in Sample 2, where we are able to control for mother's education polygenic score. Here one standard deviation increase in the child's polygenic score is associated with a 0.074*** (se=0.012) standard deviation increase in parenting (Model 3). This estimate drops to 0.034** (se=0.013) when we control for the mother's education polygenic score and the father's education and occupation (model 4). In comparison, this is about a fourth of the increase in parenting associated with having a female child (0.126***, se=0.020, Table A3). In Model 4, the post-hoc statistical power for the child polygenic score in this model is 61 %.

Finally we also run the analysis in Sample 3, which provides us the possibility of control for both the mother's and the father's education polygenic score. As explained in the Analytical Strategy section, this design will ensure that the variation left in the child's education polygenic score is exogenous. Sample 3, however, consists of 1,404 children, and the post-hoc statistical power for the child's education polygenic score is only 23 % (Model 6), which gives us too slim of a change to discover a true positive effect. We show the results to assess whether the coefficients are comparable in direction and magnitude. In the fully controlled Model 6, the coefficient it 0.044 (se=0.031), which resembles closely the results from Sample 1 and 2. The results from Sample 3 thereby supports the results from Sample 1 and Sample 2.

In sum the regression results suggest that parents reinforce children's genetic propensity towards educational success by providing more cognitively stimulating activities to children with higher polygenic scores.

Socioeconomic Differences in Parenting Response to Children's Education Polygenic Score

Finally, we turn to our second research question, whether socioeconomically advantaged families compensate children with low genetic propensity towards educational success. We regress parenting on interaction terms between child's education polygenic score and (1) university degree as highest parental education, (2) professional occupation as highest parental occupation, and (3) weekly family income above 400 UKP, respectively. Figure 3 shows the interaction term coefficients and their 95% confidence intervals for each sample (full regression results are display in Table A4). In Sample 1, we control for child's sex and principal components, in Sample 2 we add mother's polygenic score, and in Sample 3 we add father's education polygenic score.

The interaction between child's education polygenic score and university degree as highest parental educational attainment is statistically significant in Sample 1 (-0.059*, se=0.024) and Sample 2 (-0.057*, se=0.026), but insignificant in the least well-powered sample, Sample 3 (-0.021, se=0.049). The direction of the coefficient is however unchanged. The interaction between child's education polygenic score and professional occupation as highest parental occupation, is also negative and statistically significant in Sample 1 (-0.060*, se=0.029) and Sample 2 (-0.065*, se=0.032), while insignificant but with unchanged direction in Sample 3 (-0.021, se=0.049). Finally, the interaction between the child's education polygenic score and having a weekly family income above 400 UKP is negative and statistically significant in Sample 1 (-0.047*, se=0.023), statistically insignificant in Sample 2 (-0.046, se=0.025) and Sample 3 (-0.053, se=0.045). In terms of direction of the all of the interactions, the analysis provides a clear pattern: all interaction terms are negative. As shown in Figures 3, the consistent pattern is that low SES parents react to their child's PGS score by investing more when it is higher, while higher SES parents invest equally across the offspring PGS distribution.

Discussion

Parenting is often conceptualized as a uni-directional socialization process. But parenting is a dynamic process, where parents respond to children's interest and attainment (Feinstein et al., 2008; Melhuish et al., 2008). As an example, children are active agents in initiating and shaping shared book reading (Hall et al., 2018; Luo & Tamis-LeMonda, 2017). The previous literature has considered parenting responses to birthweight, early cognitive skills, and school performance (Abufhele et al., 2017; Aizer & Cunha, 2012; Grätz & Torche, 2016; Hsin, 2012; Quadlin, 2015; Restrepo, 2016). Most recently children's genetic propensity towards educational success has been shown to influence parenting during middle childhood (Wertz et al., 2018). While parents matter throughout children's lives, the early years are especially critical to child development: Both socioeconomic and genetic disparities in cognitive skills show up before school age (Belsky et al., 2016; Feinstein, 2003), and parental investments in this period can have effects well into adulthood (Gertler et al., 2014). Furthermore, parenting responses to other child characteristics are often dependent on family socioeconomic status (Aizer & Cunha, 2012; Grätz & Torche, 2016; Hsin, 2012; Restrepo, 2016). We do not know whether socioeconomic status affects the parenting response to children's genetic makeup. In this study, we consider the effect of children's genetic propensity towards educational success on cognitively stimulating parenting during early childhood (age 6 months to 4 years and 9 months), and where this effect varies across family socioeconomic status.

Our study has several methodological advantages. First, we draw on molecular genetic data to construct education polygenic scores using the newest GWAS results (J. J. Lee et al., 2018), which gives us a direct measure of children's and parents' genotype. Second, we control for the mother's education polygenic score and social mediators of the father's genotype, plausibly rendering the variation in the child' education polygenic score exogenous. Third, a large sample size (N=5,714 for our preferred model9 allows for a statistically well-powered analysis (post-hoc power = 61%). Using this research design, we find that children's education polygenic score is associated with cognitively stimulating parenting. An increase of one standard deviation in the children's education polygenic scores elicits additional 3 % of a standard deviation of parenting. However, this association vary across family socioeconomic status. Relative to less advantage families, university educated, professional, high income families compensate children with low education polygenic scores.

A limitation of our study is that in order to achieve enough statistical power, we do not control directly for father's genotype since this variable is only available for a small subsample (N=1,404). The effect of the education polygenic score of the child on parenting could be exaggerated if it is driven by the genetic make-up of the father. We address this issue by analyzing the direction and magnitude of the coefficients in the smaller subsample that contains father's genotype. These results support our main findings.

Our study has several theoretical implications. First, while we know that educational attainment has a genetic component (Branigan et al., 2013; Conley et al., 2015), the mechanism are unclear. It is an old idea within sociology that genotype elicit certain response from the social environment such as parents and that these response creates the outcome (Jencks, 1980). Up until recently, this hypothesis was untestable. Our study provides the first evidence, that children's genetic propensity towards educational success affects the amount of cognitive stimulation they receive in early childhood.

Second, we find that the parenting response to child's genotype is contingent on the family socioeconomic status. Is key in much sociological theorizing about intergenerational transmission of inequality, that socioeconomically advantaged families can draw on more economic, social, and cultural resources to compensate for negative child development or reinforce positive child development (Bernardi, 2014; Conley, 2004; Lareau, 2011; Lucas, 2001). As such, our study draws on a long tradition with the sociology of stratification. However, our study provides the first evidence of compensatory advantage in terms of parenting responses to children's genotype. This is more than just 'another' child characteristic that advantage families can afford to act on differently than disadvantage families. This finding highlights the complex interplay between social and genetic factors in creating the outcomes we observe. In the decades to come, where genotyping will become cheaper, and potentially and everyday tool, it is important to keep in mind that genetic effects are contingent on social factors and cannot be seen in isolation from the social environment.

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Tables and Figures

Table 1 Means and Standard Deviations

	Sample 1		Sample 2		Sample 2	
	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev
Parenting Score						
Age 18-57 months	0.04	0.93	0.07	0.90	0.10	0.84
Age 6 months	0.02	0.98	0.04	0.97	0.11	0.93
Polygenic scores for educational attainment						
Child	6.47^{E-05}	3.92^{E-06}	6.48^{E-05}	3.91^{E-06}	6.56^{E-05}	3.91^{E-06}
Mother	0	0	6.48^{E-05}	3.86^{E-06}	6.55^{E-05}	3.90^{E-06}
Father	0	0	0	0	6.56^{E-05}	3.59^{E-06}
Female child	0.49	0.50	0.50	0.50	0.47	0.50
Mother's educational attainment						
CSE or vocational	0.23	0.42	0.21	0.41	0.14	0.35
O Level	0.35	0.48	0.35	0.48	0.31	0.46
A Level	0.25	0.43	0.26	0.44	0.31	0.46
Degree	0.15	0.36	0.16	0.37	0.24	0.42
Missing education	0.02	0.15	0.02	0.14	0.01	0.09
Father's educational attainment						
CSE or vocational	0.27	0.45	0.27	0.44	0.16	0.37
O Level	0.21	0.41	0.21	0.41	0.21	0.40
A Level	0.26	0.44	0.27	0.44	0.30	0.46
Degree	0.20	0.40	0.21	0.41	0.31	0.46
Missing education	0.05	0.22	0.04	0.20	0.02	0.12

Note: variables were standardized before samples were defined

Table 1 *Continued*

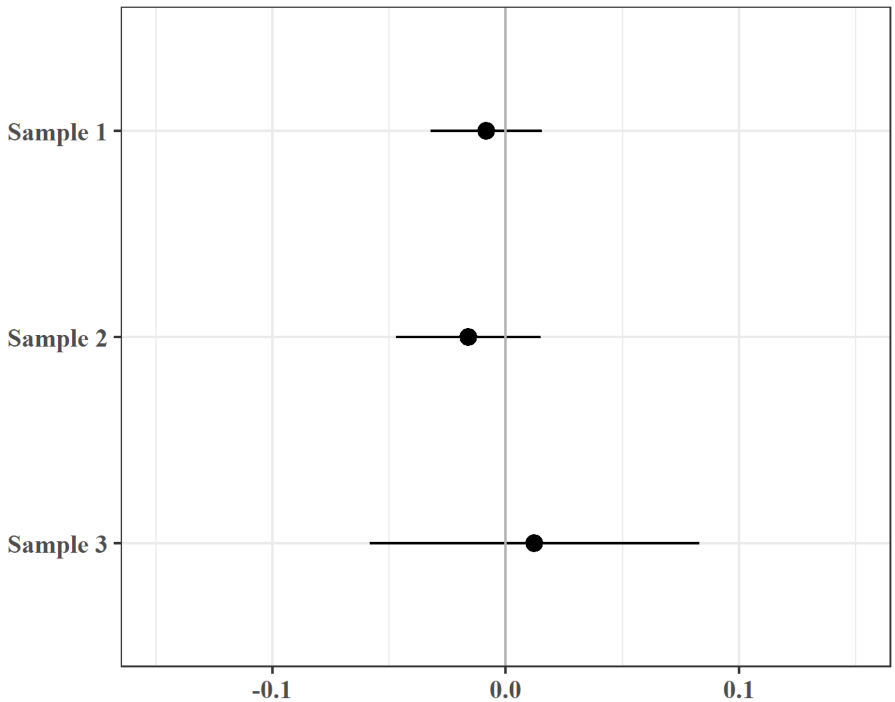
	Sample 1		Sample 2		Sample 2	
	Mean	Std. dev	Mean	Std. dev	Mean	Std. dev
Mother's occupational class						
V – Unskilled	0.03	0.17	0.03	0.16	0.01	0.12
IV - Semi-skilled	0.15	0.36	0.14	0.35	0.11	0.31
III – Manual	0.05	0.21	0.04	0.21	0.05	0.21
III - Non-manual	0.41	0.49	0.41	0.49	0.38	0.49
II – Man. or tech.	0.31	0.46	0.32	0.46	0.37	0.48
I – Professional	0.04	0.19	0.04	0.20	0.07	0.25
Missing occupation	0.02	0.14	0.02	0.13	0.00	0.06
Father's occupational class						
V – Unskilled	0.03	0.17	0.03	0.17	0.02	0.15
IV - Semi-skilled	0.06	0.25	0.06	0.25	0.05	0.21
III – Manual	0.34	0.47	0.33	0.47	0.25	0.43
III - Non-manual	0.13	0.33	0.13	0.34	0.16	0.36
II – Man. or tech.	0.31	0.46	0.31	0.46	0.37	0.48
I – Professional	0.09	0.29	0.10	0.29	0.14	0.35
Missing occupation	0.04	0.21	0.04	0.19	0.01	0.09
Std. family income	0.09	0.90	0.12	0.90	0.38	0.81
Missing income	0.11	0.31	0.09	0.29	0.04	0.20
Highest parental SES indicator						
Degree	0.25	0.43	0.26	0.44	0.37	0.48
Professional occupation	0.11	0.32	0.12	0.32	0.18	0.38
Weekly family income > 400 UKP	0.29	0.46	0.30	0.46	0.40	0.49

Note: variables were standardized before samples were defined

Table 2 Parenting Items ("How often do you do these activities with your baby/toddler?")

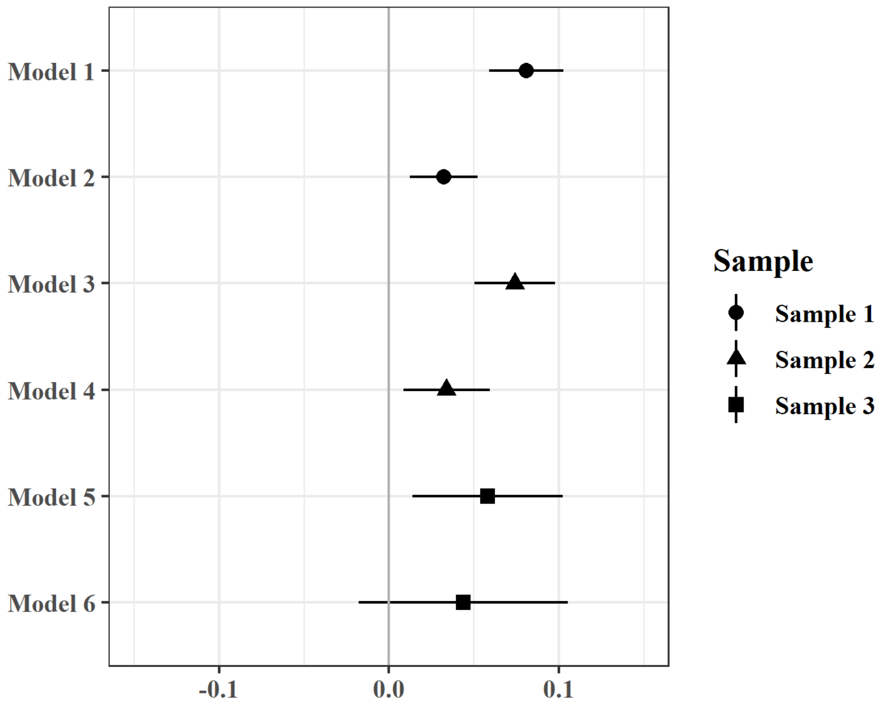
	Age in months				
	6	18	24	38	57
Sing to child	x	x	x	x	x
Show child pictures in books	x	.	.	x	.
Read stories or show child pictures in books	.	x	.	.	.
Read child stories	.	.	x	.	x
Play with toys	x	x	.	x	x
Cuddle child	x	x	x	x	x
Physical play (e.g. clapping, rolling over)	x	x	.	x	.
Take child for walks	x	x	.	x	.
Imitation games (pat-a-cake, peek-a-boo)	.	x	.	.	.
Go out to a park or playground with child	.	.	x	.	x
Active play (eg. ball games, hide and seek)	.	.	.	.	x
Takes child swimming	.	.	.	.	x
Draws or paints with child	.	.	.	.	x
Cronbach's alpha	0.52	0.68	0.45	0.66	0.73

Figure 1 Parenting during Infancy (Age 6 Months) Regressed on Child's Polygenic Score



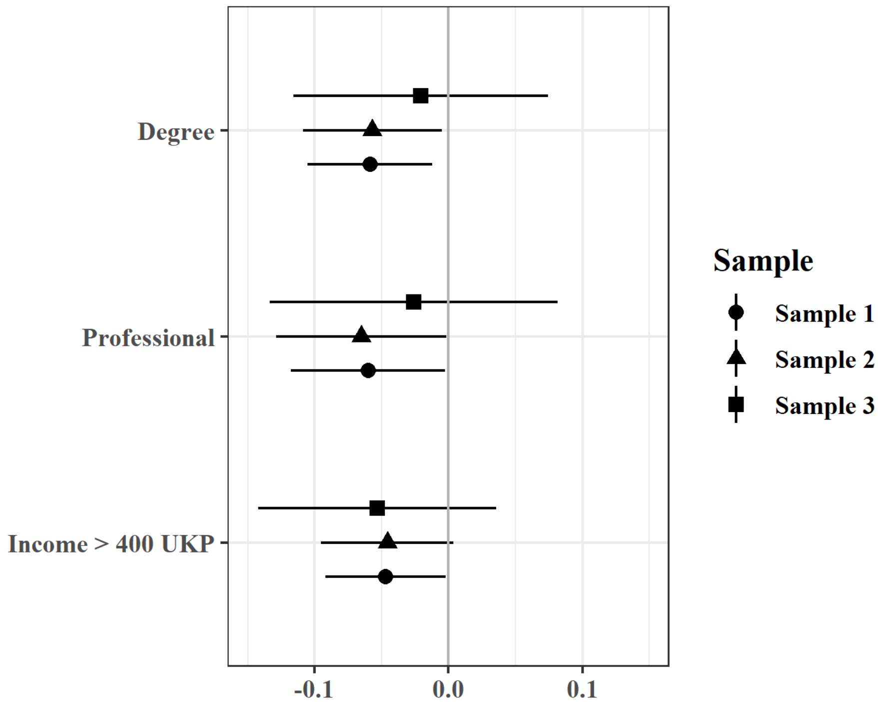
Note: 95 % confidence intervals are calculated from cluster robust standard errors.

Figure 2 Parenting during Early Childhood Regressed on Child's Polygenic Score



Note: 95 % confidence intervals are calculated from cluster robust standard errors.

Figure 3 Parenting during Early Childhood Regressed on Child's Polygenic Score by Socioeconomic Status



Note: 95 % confidence intervals are calculated from cluster robust standard errors.