Parental Separation and Children's Genetic Influences on Education across 20th Century Birth Cohorts

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Abstract

Whether the family context matters for genetic influences on children's educational attainment remains an open question. Previous research mainly considers parents' socio-economic standing and overlooks a key dimension of social stratification: childhood family structure. We focus on the extent that parental separation affects genetic influences on educational attainment across 20th Century birth cohorts. This study draws on the US Health and Retirement Study (HRS) to estimate the association between education polygenic scores and educational attainment of adults born across the 20th Century who experienced a parental separation before age 16 compared to adults who lived continuously with both parents. We find that genetic effects are smaller for adults whose parents separated compared to adults whose parents remained coupled. Moreover, the magnitude of genetic effects remained constant across cohorts for adults from two-parent households, but decreased for adults whose parents separated. Additional analyses based on the comparison with adults who lost a parent during childhood indicated that family instability rather than parental absence suppresses genetic effects among those whose parents separated. Our findings highlight the importance of socio-historic variation in distinct family conditions linked to parental separation that in turn affect children's chances to tap their genetic potential for education.

Keywords

Parental separation, education, gene-environment interactions, cohort comparison

INTRODUCTION

Decades of research have focused on how family instability during childhood, especially parental separation, negatively affects children's educational outcomes (Amato 2010, 2010; Amato and Keith 1991; Lee and McLanahan 2015; Raley and Sweeney 2020; Thomson, Hanson, and McLanahan 1994). Not only is children's educational success affected by social resources associated with parental socioeconomic status or childhood family structure, but also by children's genes (Belsky et al. 2016; Lee et al. 2018; Liu 2018; Nielsen 2006). However whether or to what extent genetic influences are realized is highly dependent on the environmental conditions that children encounter (Bronfenbrenner and Ceci 1994). An established line of research has focused on the importance of parents' socio-economic standing and examined whether genetic influences on cognitive abilities and education are stronger for children that grow up in socioeconomically advantaged families (e.g., Baier and Lang 2019; Conley et al. 2015; Erola et al. 2021; Figlio et al. 2017; Gottschling et al. 2019; Guo and Stearns 2002; Lin 2020; Turkheimer et al. 2003). These studies argue that advantaged parents provide resource-rich environmental conditions that are tailored to children's needs and facilitate the realization of genetic influences on IQ (Rowe, Jacobson, and Oord 1999; Scarr-Salapatek 1971). Yet, few studies have gone beyond dimensions of socioeconomic status as indicator for children's (dis-)advantage to assess the increasingly important role of childhood family structure and instability.

However, a thorough understanding of the how social background affects children's educational attainment – including how childhood family instability impacts the importance of genes for education – is essential when designing policies to mitigate disadvantage across the life course and historical time. Research on whether and how childhood family structure moderates the link between genes and educational attainment is scarce. Most studies in this area are interested in a genetically sensitive approach to estimating the causal effect of divorce

on educational attainment (e.g., D’Onofrio et al. 2005, 2006, 2007; Guo, Roettger, and Cai 2008; Nederhof et al. 2012; Waldman 2007). A recent study assessed how parental separation moderated the link between genes and educational attainment on a sample of twins born in Germany in the early 2000s (Baier and Winkle 2020). They showed that parental separation lowered the relative importance of genetic influences on children’s school related outcomes during middle childhood. Moreover, the study provided some evidence that socio-economic differences between parents who separated and those who remained coupled did not drive their findings. Despite the valuable insights of the study, these findings may not be transferable to other countries or historical periods, especially in light of variation in the intergenerational consequences of parental separation across socio-historic contexts (Kreidl, Štípková, and Hubatková 2017).

This paper extends previous genetically sensitive studies by posing three novel research questions: First, are genetic influences on education smaller among adults who experienced a parental separation during childhood compared to those who grew up in stable two parent families in the United States? We therefore shift attention to the United States as a liberal welfare state known for its high levels of social inequality (Esping-Andersen 1990, 1999) and low levels of protection against the adverse consequences of life course risks, such as divorce (DiPrete 2002). Second, are there cohort differences in the importance of genetic influences on education for adults who experienced a parental separation during childhood compared to those who grew up in stable two parent families? This allows us to assess whether differences in genetic influences on education by childhood family structure represent a recent phenomenon or a persistent disadvantage. Third, is the importance of genetic influences on education for adults who experienced a parental death during childhood more similar to adults who experienced a parental separation or those who grew up in stable two parent families? Specifically, we use parental death as a second reference category to adjudicate whether

mechanisms related to family instability, parental absence, or economic disadvantage are the driving force behind any family structure differences we might find.

In this study, we draw on molecular genetic and life history data from the US Health and Retirement Study (HRS) to empirically assess our research questions. Specifically, we estimate the importance of genes for educational attainment by regressing adults' years of education on their education polygenic score (PGS) adjusted for socio-economic differences by family structure. In general terms, the education PGS provides a weighted sum score of measured genetic factors that affect education attainment and can be used to estimate genetic effects on education. We then use retrospective life history data to estimate how genetic effects on education vary for adults who experienced a parental separation or divorce before age 16, adults who lost a parent before age 16, and adults who lived continuously with both parents until age 16.

We are the first to provide empirical evidence using molecular genetic data that the importance of genes for education is lower for adults whose parents separated before age 16 compared to those who remained coupled in the United States. Moreover, we show astounding birth cohort trends between the two groups: while the importance of genes for education tends to remain constant across birth cohorts for adults from continuous two parent households, the strength of genetic influences declined across birth cohorts for adults who experienced a parental separation. In addition, we show that the impact of genetic influences on education across cohorts for adults who lost a parent before age 16 more closely reflects the trend for adults who grew up in two parent households. This suggests that parental conflict and stress related to family instability rather than the reduction in social networks and ability for social monitoring are the main mechanism that suppress genetic influences on education for adults whose parents separated during childhood.

In the following sections, we first provide an overview of research on the variation in genetic influences on education across social backgrounds. We then outline our theoretical arguments and formulate hypotheses on the link between parental separation and children's chances to tap their genetic potential for education in the United States, how the impact of childhood family structure on the importance of genes varies across birth cohorts, and finally how parental death can be used as a second reference group to indirectly test for the mechanisms driving cohort change in genetic influences on education across family structure groups. After reviewing the data and methods and displaying our results, we end with a discussion of routes for future research and policy implications.

PREVIOUS RESEARCH

To conceptualize how social conditions affect genetic influences on education researchers often refer to the Scarr-Rowe hypothesis, which states that genetic effects on IQ are stronger in enriched social settings (Rowe et al. 1999; Scarr-Salapatek 1971). The underlying mechanism linking enriched environments and genetic effects on IQ is thought to be enhancement, which describes how resource-rich environments push individual development to its limits and foster the realization of genetic potential (Shanahan and Hofer 2005). In contrast, resource-poor environmental conditions tend to suppress the development of genetic potential. The starting point of the Scarr-Rowe and enhancement mechanisms is the bio-ecological model according to which humans develop in permanent exchange with environmental influences set by immediate environments, such as parents, but also more distal contextual levels, such as institutions (Bronfenbrenner and Ceci, 1994). Thus, whether or to what extent individuals realize their genetic endowments depends on specific aspects of the environment they encounter.

Previous research on the Scarr-Rowe hypothesis has mainly focused on cognitive ability (e.g., Figlio et al., 2017; Guo and Stearns, 2002; Turkheimer et al., 2003; Gottschling et al. 2017), although recent studies shifted the focus to education (e.g., Baier and Lang 2019; Conley et al. 2015; Domingue et al. 2015; Erola et al. 2021; Lin 2020). Nearly all studies on the Scarr-Rowe hypothesis used some indicator of parents' social standing to capture differences in the quality of the rearing environment. These studies typically argue that enhancement is mainly found in socio-economically advantaged family contexts, because parents provide environmental conditions and tailored inputs for their children that facilitate genetic expression.

Empirical findings on educational outcomes are mixed. Twin based studies provide support for a Scarr-Rowe Interaction (SRI) in Germany (Baier and Lang 2019) and Finland (Erola et al. 2021). In twin based studies genetic influences are not measured directly, but inferred by the comparison of mono- and dizygotic twins (Plomin et al. 2008). Studies also used direct measures for genetic influences, such as PGS for education based on large genome-wide association studies (GWAS). A recent study for Norway does not report any systematic variation in education PGS by parental social background (Isunget et al. 2021), while findings for the United States remain mixed (Conley et al. 2015; Domingue et al. 2015). A recent study by Lin (2020) used the most recent, and therefore more predictive educational PGS (Lee et al. 2018), and found that the importance of genes tends to decrease by parents' education. Divergent findings may be explained in light of methodological differences, but also hint at the importance of the contextual differences between countries and cohorts.

A more substantive limitation of this strand of research is the narrow focus on parents' structural stratification characteristics, such as parents' socio-economic standing, which neglects the pivotal role of household and demographic characteristics, such as family structure. In the last decades, changes in family and household composition are one of the

largest changes across recent decades in a number of high income countries with consequences for both adults and children (Amato 2001, 2001, 2010; Cherlin 2010; Raley and Sweeney 2020). Especially in the United States, household income differences by family composition have become increasingly larger (McCall and Percheski 2010) and family structure is now one of the main means through which inequalities are reproduced across generations (McLanahan 2004; McLanahan and Percheski 2008).

Few studies have acknowledged the importance of family structure for children's chances to realize their genetic potential for education. Early studies that used molecular approaches focused on how parental separation lowered genetic effects on children's problem behaviour (Nederhof et al., 2012; Guo, Roettger, and Cai 2008; Waldman 2007). However, these studies relied on a candidate-gene approach, which has been heavily criticised due to low replicability (e.g., Duncan and Keller 2011 Dalton and Fletcher 2017). To date, no studies have applied more advanced molecular genome-wide approaches, such as PGSs. Two studies using a twin design reported a similar finding, but studied children's internalizing and externalizing behaviour in the United States and the Netherlands (Robbers et al. 2012; Hicks et al. 2009). A recent twin study concentrated on educational attainment and showed that parental separation lowered genetic influences on school related skills for children born in the early 2000s in Germany (Baier and Winkle, 2020). However, twin models come with strong assumptions, which can lead to biased estimates if violated (Horwitz, Videon, and Schmitz 2003). For example, it is assumed that monozygotic twins do not mutually influence one another more than dizygotic twins (Conley et al. 2013). We are the first to provide a molecular based analysis on how family structure moderates genetic effects on education based on the newest PGSs for education (Lee et al. 2018) and circumvent the strong assumptions made in classical twin design.

THEORETICAL BACKGROUND

Parental Separation & Genetic influences on Education

To theorize about the relationship between parental separation and children's chances for educational success we build on three major theoretical accounts: the family instability, the parental absence, and the economic disadvantage perspectives (Amato 2001, 2010; Amato and Keith 1991; Biblarz and Gottainer 2000). The family instability perspective concentrates on the adverse psychological consequences of separation (Cavanagh and Fomby 2019). Accordingly, parental distress, conflict, and adverse living conditions linked to parents' separation and divorce affect family climate, create tension, and change how parents treat their children and parent-child relationships. Increased levels of stress and conflict lower a parent's capacity to provide emotional support and to respond adequately to children's socio-emotional needs. The resulting relationship instability and more distant parenting can increase behavioural problems and lower educational performance (Spera 2005).

The parental absence perspective states that being raised with two parents in one household has advantages for children over living with one parent. Some have emphasized that different socialization patterns between one and two parent households. For example, children may learn to internalize power dynamics and to adhere to rules better, because interactions with two parents are more often hierarchically structured than interactions with a single parents. Moreover, two parents have more time resources to provide better rearing conditions for children compared to a single parent. Specifically, this perspective adds the notion that it is more difficult for single parents to control children's enrichment activities and to monitor their educational progress compared to two parent families due to both greater time constraints and a more limited social network. Previous research has shown that lower levels of parental monitoring impedes children's development and is negatively associated with children's

educational attainment (Fröjd, Kaltiala-Heino, and Rimpelä 2007; Kerr, Stattin, and Burk 2010).

Lastly, the economic disadvantage perspective emphasises that parents who divorce or separate tend to have a lower socio-economic standing than parents who stay together. In addition, this perspective emphasizes the economic consequences linked to a separation. Single parents have lower household incomes and at the same time they often have to reduce their time in the labour-market due to increased child-care responsibilities. The resulting economic strain affects children's educational achievements for several reasons. It prevents parents from providing a stimulating home-environment and good learning opportunities which furthers the development of children's cognitive and non-cognitive skills and their academic progress (e.g., Cunha and Heckman 2008). Additionally, more advantaged parents can afford better schools, private instructors, additional learning materials, and extra-curricular activities also contributing to children's educational success.

Together, these three theoretical accounts propose different mechanisms that explain how the adverse consequences of separation affect children's educational outcomes. As previously discussed parental separation may not only be linked to children's education but also to their chances to fulfil their genetic potential (see Figure 1). Building on previous work (Baier and Winkle 2020), we argue that parental separation and its related family processes and circumstances carry environmental features that can moderate genetic influences on education, i.e. a gene-environment interaction (GxE).

However, it is important to note that gene-environmental correlations (rGE) may also generate family structure differences in the genetic effects on education. Genetic influences on divorce are well-established in the literature (McGue and Lykken 1992; Salvatore et al. 2018; Van Winkle and Conley 2021). If genetically influenced personality characteristics affect both

the likelihood of parental separation as well as children's problem behaviour and/or their education, then the adverse consequences of parental separation may run through shared genes and not through the environmental exposure to parental separation.

Several studies have investigated to what extent rGE drives the impact of separation or divorce (see for a review Amato 2010). These studies used quantitative approaches rooted in behavioural genetics that disentangle genetic from environmental influences (see Plomin et al. 2008), mostly exploiting adoption or children of twin (CoT) designs. For children's internalizing and abnormal behaviour, studies show that the negative impact of separation is not driven by shared genetics (O'Connor et al. 2000; D'Onofrio et al. 2005, D'Onofrio et al. 2006). Evidence for educational outcomes is mixed and differ by indicator: O'Conner and collaborators (2000), find support for rGE for children's reading competency, parental reports on children's achievement, and children's self-reported attitudes about educational achievement. In contrast, D'Onofrio and colleagues (2005) find no support for rGE when assessing grade repetition and years of education. Overall, previous research finds little or no evidence for rGE, and concludes that rGE does not seem the driving force behind the negative impact of parental separation or divorce on children's achievements (Amato 2010).

Figure 1. Conceptual Framework: Parental Separation as Moderator for Genetic Influences on Educational Attainment.

Integrating the three main theoretical accounts – the family instability, the absence of a parent, and the economic disadvantage perspectives – we expect that parental separation impedes the enhancement mechanism for the following reasons (see Figure 1). First, separation triggers family stress and conflict which changes parental behaviour and leads to lower emotional support and unstable parent-child relationships. Children that experience a

separation are exposed to increased levels of stress for children, which are negatively linked to children's cognitive development and likely their related genetic influences (Lupien et al. 2009). Second, owing to time limitations and a loss in the social networks, single parents have less control over children's affairs and a lower capacity to monitor their educational progress. Both, a change in parent-child interactions and lower involvement in children's affairs are linked to fewer inputs tailored to their children's needs, thereby lowering children's developmental opportunities and chances to fulfil their genetic potential. Third, parental separation leads to economic strain and discontinuities in living standards, which prevent parents from providing stable and enriched home-environments under which enhancement can take place. In sum, we expect that genetic effects on education will be weaker among adults who experienced a parental separation during childhood compared to those who grew up in stable families in the United States (hypothesis 1).

Parental Separation & the Importance of Genes for Education across Birth Cohorts

Previous research demonstrates that genetic influences on education are sensitive to historical change. Early twin based studies for Norway, and an international meta-analysis found that genetic influences on education increased over the 20th Century (Branigan, McCallum, and Freese 2013; Heath et al. 1985; Tambs et al. 1989). This trend was also recently found for the United States based on education PGS, although genetic influences on education increased only slightly across cohorts born from 1920 to 1959 (Lin 2020). The increase in the importance of genetic influences on education is often explained with the shift towards more egalitarian access to education. Findings for Spain evaluating educational reforms implemented in the 1970 support this interpretation (Colodro-Conde et al. 2015). With few exceptions (Baker et

al. 1996; Silventoinen et al. 2020), the literature mainly concludes that genetic influences on education increased over the twentieth century.

We argue that the overall trend will differ by childhood family structure, because of the increase in parental separation and divorce in the United States and related socio-cultural changes during the 20th Century, such as the liberalization of divorce legislation and increasing female labor market participation. At the beginning of the 20th Century, less than five percent of married adults divorced, while the rate doubled by the 1960s and peaked with 23 percent in the 1980s, although divorce rates have declined somewhat in recent decades (Schweizer 2020). This increase in the 1960s was accompanied by the introduction of no-fault divorce legislation that made divorce more accessible, because spouses no longer needed to provide proof of misbehavior, e.g. adultery, physical or emotional violence. No-fault divorce legislation was implemented in nearly all US States by the mid-1970s (e.g., Buehler 1995).

Previous research demonstrated that the negative selection into parental separation and divorce increased over the second half of the 20th Century as highly educated adults are increasingly less likely to divorce or separate than less educated adults (Cherlin 2010; Härkönen and Dronkers 2006; Martin 2006; Ono 2009; Raley and Bumpass 2003). However, we know little about the parameters that drove divorce decisions before the mid-20th Century. As divorces were rare, it is likely that the process of divorce was linked to high social and economic costs, therefore potentially more likely among more privileged social groups. However, due to the lack of survey data for these early cohorts, the notion of a positive selection into divorce remains speculative.

Social policies can mitigate the adverse consequences of negative life events, such as divorce or separation, for individuals as well as their household (DiPrete 2002; DiPrete and McManus 2000). For the United States, institutionalized protection is comparatively low

(DiPrete 2002). Custodial parents – in most cases mothers – with dependent children can qualify for the AFDC (Aid to Families with Dependent Children) (see Biblarz and Gottainer 2000). AFDC is a means-tested program for child support and hence, not dependent on the marital status. However, AFDC benefits are not enough to secure household incomes above the poverty threshold (Waldfogel et al. 2001). In many cases separated mothers apply for food stamps or Medicare, programs that are also not targeted to lone-motherhood. AFDC was introduced in 1935 as part of the New Deal, but was replaced by TANF in 1996 (Temporary Assistance to Needy Families), which shortened the amount of time that mothers can receive support.

Policies regulating post-separation private income transfers between spouses have also changed across the 20th Century. Alimonies or spousal support were granted before no-fault legislation was introduced (Shehan et al. 2002), although previous studies document that they were awarded to a rather small proportion of women (about 15%, Kelly and Fox 1993 according to Shehan et al. 2002). Non-custodial parents are obliged to provide financial support to the main care giver – in most cases mothers. However, until the introduction of the “Family Support Act” regulations in 1988, the guidelines for child support differed widely across states and custodial parents often received no or inadequate economic support (see Grell 2011). The new nation-wide child support system attempted to ensure adequate payments for custodial parents. The most common scheme intends for a child to receive as much as if the parents had not separated by means of income sharing between former spouses. Using data from the year 2000, a study found that the amount that is paid per child is high in the United States compared to other countries (Skinner, Davidson, and Bradshaw 2008). However, underpayment may still induce post-separation economic deprivation and uncertainty, and household income differences between single and two parent households have continued to grow despite institutional change (McCall and Percheski 2010).

The increasing negative social gradient in divorce and separation across the second half of the 20th Century, including greater economic hardship, discontinuities in living standards and adverse psychological consequences, may have further strengthened the negative impact of both family instability and parental absence (see Figure 1). Increasing economic difficulties have likely increased separation-related stress and conflict. While the threshold to separation may have lessened across cohorts and even low levels of parental conflict may lead to separation, family tension and parental conflict over future living arrangements and financial security have increased as mothers' economic situations worsened (Van Winkle and Struffolino 2018). In addition, separated mothers needed to spend more time on the labor market to secure their economic wellbeing (Van Winkle and Leopold 2021), further reducing their ability to invest time in controlling and monitoring their children's activities and educational performance. Therefore, as custodial parents became more exposed to the consequences of separation, they are increasingly constrained in their ability to provide the rearing conditions for their children that foster the realization of genetic potential. In sum, we expect that the importance of genes for education among adults who experienced a parental separation during childhood declined across birth cohorts relative to those who grew up in stable families in the United States (hypothesis 2).

Parental Separation, Parental Death & the Importance of Genes for Education

In our previous discussion linking parental separation to the importance of genes for education, we concentrated on three common theoretical approaches in the literature: the family instability, parental absence, and economic disadvantage perspectives. Previous research has been unable to inch towards identifying the main mechanisms driving the moderating effects of parental separation on the relationship between genetic factors and education.

In line with previous research we use parental death as second comparison group to explore the driving mechanisms (e.g., Amato and Anthony 2014; Biblarz and Gottainer 2000; Cherlin, Kiernan, and Chase-Lansdale 1995; Sapharas et al. 2016). On the one hand, one might expect that the consequences of parental death are similar to children who lived with both parents because parental death is thought to be considerably more random than parental separation. For example, family instability and conflict should on average be the same across both groups, because death is not generally preceded and proceeded by conflict as is the case with separation. In addition, there is less selection into death compared to separation. Although one might suspect some health or socio-economic selection into parental death or post-death socio-economic disadvantages, these pre-death selection and post-death differences are smaller than assumed. Amato and Anthony (2014), for instance, demonstrated based on US Census data that the main reason for death among those in reproductive age, 25 and 44 year olds, is an unintended accident. Furthermore, the socio-economic consequences of parental death are less severe than for separation, because social benefits are more generous and not-means tested (see Biblarz and Gottainer 2000). Both, spouses (up to the age of 60) and their children (up to the age of 18) are eligible for monthly survivor benefits. If the spouse continues to work, they continue to receive these benefits up to a certain threshold, while children's benefits are paid independent of the surviving parent's income and labor market status. On the other hand, one could also argue that the consequences of parental death should be more similar to the consequences of parental separation. For the custodial parent, both separation and death result in a reduced network and a lower capacity to control and monitor their children's activity.

The comparison of parental separation with parental death enables us to explore whether a negative impact on children's chances to express their genetic potential is driven by family instability, the absence of a parent, or economic disadvantage. Yet, it is likely that death and separation are each linked to unique experiences, which lowers the comparability of these

two family conditions. We therefore treat the comparison with children who lost a parent as an indirect test for the proposed mechanisms. As we discuss below, we adjust all models for socioeconomic status of the parental household during childhood in an attempt to capture selection and socio-economic differences related to family structure. Therefore, if the importance of genetic influences on education is similar among adults who experienced a parental death and those who lived with both parents, then family instability mechanisms drive the moderating effect of parental separation (hypothesis 3a). In contrast, if the importance of genes for education is similar among adults who experienced a parental death and those who experienced a separation during childhood, then parental absence mechanisms drive the moderating effect of parental separation (hypothesis 3b).

DATA & METHODS

Study Sample

We draw on data from the US Health and Retirement Study (HRS) to test our hypotheses. The original HRS cohort sampled in 1992 consisted of adults born 1931-1941 and their partners. In the following year, a second study cohort, the Asset and Health Dynamics among the Oldest Old, with adults born before 1924 was collected. Both cohorts were interviewed in 1998 when two additional cohorts were introduced to the study: the Children of the Great Depression born between 1924 and 1930 and the War Babies born between 1942 and 1947. Since then a sample has been added every three waves, i.e. six years, up to the most recent Late Baby Boomer cohort born between 1960 and 1965. Therefore, the HRS enables us to investigate intergenerational consequences on children's chances to fulfil their genetic potential covering an exceptionally long time period. Other US data sets that contain genotyped data, such as the

AddHealth study, do not allow for such cohort comparisons as it provides solely information for 7th to 12th grades collected in the school year 1994/1995.

The analytical sample includes respondents and spouses that participated in enhanced face-to-face interviews between 2006 and 2012 as well as those who completed a life history mail survey fielded in 2015 and 2017. Genotyped data measuring a sample of approximately 2.4 million single nucleotide polymorphisms (SNP)ⁱ were obtained from respondents' saliva samples collected during the enhanced interviews using the Illumina HumanOmni2.5 BeadChips. We follow the convention in the literature and restrict our sample to persons of European ancestry (see Ware et al. 2018 for more information). In the life history mail questionnaires, respondents were asked to provide information on their living circumstances before the age of 16, including information on parental separation and death. 6,509 persons of European ancestry participated in an enhanced face-to-face interviews as well as completed a life history mail questionnaires. In addition, we are able to include an additional 170 respondents who were asked a subset of childhood family structure questions during the third wave, bringing our gross sample to 6,679 respondents and partners born between 1913 and 1980.

Focus Variables

We measure respondents' *educational attainment* as the number of years of schooling based on the highest degree attained (see Herd et al. 2019). In addition, we conducted analyses based on two binary outcomes as a robustness check: whether respondents acquired more than a high school education and whether respondents attained a tertiary degree. The results of these analyses are similar to those presented below and lead to the same substantive conclusions.

To estimate the impact of genetic effects on educational attainment, we draw on the 2018 *educational attainment PGS* available in scientific use files by the HRS data providers (Ware et al. 2018). A PGS can be understood as a single score indicating an individual's genetic propensity for a trait. Specifically, a PGS is the weighted sum of common genetic variants or number of reference alleles at SNPs shown to be related with educational attainment in large scale genome-wide association studies (GWAS). The education PGS we use is based on results by the Social Science Genetic Association Consortium (SSGAC), which identified genome-wide significant SNPs at 1,271 loci and accounted for 11-13 percent of the variance in educational attainment in a sample of roughly 1.1 million individuals (see Lee et al. 2018). Note that the results reported below use the PGS constructed without data provided by 23andMe, however analyses performed with a PGS including 23andMe weights provided substantively similar results. Per definition, the education PGS is standardized and normally distributed with a mean of zero and a standard deviation of one.

Our *childhood family structure* variable is based on a number of questions in the life history mail surveys. Respondents were asked whether, before the age of 16, they: a) lived in a children's home or orphanage, b) with a foster family or in a foster home, c) in a boarding school, d) whether their biological or adoptive parents ever separated or divorced, e) or died, f) whether one or more siblings died, g) whether they were ever separated from their mother for longer than six months, h) or their father, and i) whether their grandparents were ever primary caregivers. In wave 3, a subset of respondents were asked whether they continuously lived with both parents up until age 16 and if not, whether this was due to death or divorce. Based on these responses we generated childhood family structure variable with five categories. The categories that we focus on are 1) whether a respondent experienced a parental divorce or separation, 2) a parental death, or 3) whether a respondent lived in a stable two parent family defined as continuously with both biological or adoptive parents until age 16

without any instable events, i.e. without any positive responses to questions a–i above. In addition, our family structure variable includes a category for individuals who experienced 4) both a parental separation and a parental death, and 5) those who experienced any other event, i.e. any positive responses to questions above except for separation, divorce and/or death.

We include an indicator to account for socio-economic selection into parental separation. We opted to include the maximum *parental education* in years as our indicator of parents' socioeconomic status. Analyses that included other indicators, such as father's occupation at age 16 or self-rated socio-economic status retrieved substantively similar results. An overview of our study sample and summary statistics of our main variables can be found in Table 1.

Table 1: Sample Summary Statistics by Childhood Family Structure

Analytical Approach

We used OLS linear regressions to estimate how the association between education PGS and educational attainment varies by childhood family structure and birth cohort. We estimate two models. First, we estimate a model including an interaction between education PGS and childhood family structure:

$$y = \beta_1 PGS + \sum_{j=1}^J \beta_{2j} Family + \sum_{j=1}^J \beta_3 PGS * Family + X\beta^* + \varepsilon \quad 1$$

where years of education, y , is regressed on education PGS, family structure and the interaction between education PGS and family structure. This allows us to test our first hypothesis as to whether genetic effects on education are weaker among adults who experienced a parental separation during childhood compared to those who grew up in stable families. Note that $X\beta^*$

here denotes a wide range of variables whose omission might induce bias, such as parents' education, gender, birth year and birth year-squared. We also include a PGS constructed for longevity to account for potential mortality bias. Finally, we include the first ten principle components to adjust for population stratification, i.e. differences in minor allele frequencies that are attributable to ancestral differences.

In a second model, we introduce interactions between the education PGS and birth year, childhood family structure and birth year, as well as a three-way interaction between the education PGS, childhood family structure and birth year:

$$y = \beta_1 PGS + \sum_{j=1}^J \beta_{2j} Family + \sum_{j=1}^J \beta_3 PGS * Family + X\beta^* + \varepsilon \quad 2$$

$$+ \beta_4 Birth + \beta_5 PGS * Birth + \sum_{j=1}^J \beta_{6j} Family * Birth + \sum_{j=1}^J \beta_7 PGS * Family * Birth$$

This allows us to test our further hypotheses on cohort change in genetic effects on educational attainment for adults who experienced a parental separation, a parental death, or who lived with both parents until age 16. We included birth year in our models as a categorical indicator as well as a linear, quadratic, and cubic term. The results below are estimated using a quadratic term for birth year, because this specification proved to fit the data best and was most parsimonious.

To account for a limited number of missing information on our independent variables (194 cases, 2.9% for childhood family structure and 244 cases, 3.7% for parental education), we use chained multiple imputations and estimate coefficients and standard errors using Rubin's rule based on 20 imputed datasets (Van Buuren et al. 2006). We omit 17 cases with missing information on our dependent variable, years of education. Results acquired by listwise deletion are substantively similar to those reported below. All analyses are weighted for

differential sampling probabilities and panel attrition. A replication package can be found at: [LINK](#).

RESULTS

Descriptive Findings

As can be seen in the summary statistics presented in Table 1, our separated sample tends to be somewhat younger than our parental death and two parent samples; born on average in 1949, 1947, and 1944, respectively. In addition, the parents of our sample who separated or died tend to be less educated than those who remained together throughout childhood, although the differences are minor: less than one year on average. Adults who lived continuously with both parents until age 16 attended school longer than adults who experienced a parental death or separation. Adults from stable two parent families had an average of 14 years of education compared to roughly 13 years for adults whose parents separated or who lost a parent.

Figure 2. Educational Attainment by Childhood Family Structure across Birth Cohorts

Figure 2 shows respondents' educational attainment by childhood family structure across birth cohorts. As expected, we see an overall increase in years spent in education between 1930 and 1960, although this increase is most prominent for adults who lived continuously with both parents until age 16. Note that we restrict the presentation of our findings to cohorts born between 1930 and 1960 due to small sample sizes at the extremes. For adults from two parent households, average educational attainment increased from over 13 to 14.5 years of schooling between the 1930 and 1955 birth cohorts. This increase began at a lower level and is less pronounced for those who experienced a parental death – from under 13

to roughly 13.5 years of schooling – and those who experienced a parental separation – from roughly 12.5 to 13.5 years of schooling.

Figure 3. Childhood Family Structure across Birth Cohorts

Cross-cohort change in the percent of adults who experienced a parental separation or death is relatively small. As can be seen in Figure 3, adults born in the early 1950s tended to live with both parents until age 16 – roughly 75 percent – compared to just over 60 percent of earlier born cohorts and 70 percent of later born cohorts. Just under 20 percent of adults born in 1930 lost a parent before age 16 compared to roughly 10 percent of adults who experienced a parental separation. The percentage of adults born in 1960 experiencing a separation increased to 15 percent compared to 10 percent of adults experiencing a parental death during childhood. There are two reasons why we observe fewer adults who experienced a parental separation before age 16 than might have been expected. First, only the 1954 cohorts and onwards would have been under age 16 between 1970 and 1980 when divorce rates in the US increased most dramatically. Second, it is possible that a majority of separations in the second half of the 20th Century were among childless couples or couples who waited to separate until their children had left the parental home (e.g., Kalmijn and Leopold 2021).

Figure 4. Distribution of Education PGS by Childhood Family Structure

Figure 4 shows the distribution of the education PGS by childhood family structure. We find a standard normal distribution with only minor and non-significant deviations across groups, which indicates that there no systematic differences among adults who grew up with

two parents, adults whose parents separated, and those who lost a parent in the distribution of education PGS (see also Table 1).

Results from Regression Models

Results from OLS linear regression models of years of education on education PGS and childhood family structure are displayed in column one of Table A1 in the appendix. As expected, we find a positive association between education PGS and educational attainment, which indicates that an increase in one standard deviation of the education PGS is associated with 0.5 more years of schooling for adults who lived in a household with both parents during childhood. Conversely, experiencing a parental separation or death is negatively associated with educational attainment. Compared to adults who lived with both parents until age 16, those who experienced a parental separation with an average education PGS have 0.8 and those who experienced a parental death have 0.6 fewer years of education.

Figure 5. Association between Education PGS and Educational Attainment by Childhood Family Structure

In line with hypothesis 1, we find some evidence that the importance of genes for educational attainment is lower for adults who experienced a parental separation compared to those who lived with both parents during childhood. Figure 5 shows the estimated association between education PGS and educational attainment for our parental separation, parental death, and two parent samples. For adults who experienced a parental separation, a one standard deviation increase in the education PGS is associated with 0.35 more years of schooling compared with the 0.5 years of schooling for those who lived with both parents as reported above. The estimated association of the education PGS of a roughly 0.4 more years of education

for adults who experienced a parental death ranges in between adults who experienced a parental and those who lived with both parents.

Results from linear regression models of educational attainment on education PGS and childhood family structure including the two- and three-way interactions with birth cohort are displayed in column two of Table A1. The association between the education PGS and educational attainment by childhood family structure and birth cohort is displayed in Figure 6. As can be seen in Figure 6, the positive association between the education PGS and educational attainment is relatively constant across our study cohorts: roughly 0.5 more years of education with a one standard deviation increase in the education PGS.

In line with our second hypothesis, we find evidence that genetic effects on education declined across our study birth cohorts for adults who experienced a parental separation. Surprisingly, the positive association between the education PGS and educational attainment was stronger for adults whose parents separated compared to adults whose parents stayed together in the early 1930s: roughly 0.94 compared to 0.51 years of education with a one standard deviation increase in the education PGS. However, for those born in the late 1930s the education PGS and educational attainment association became weaker for those who separated compared to two parent sample and no longer statistically different from zero from the mid-1940s birth cohort onwards. Although there is some indication of a recuperation in the following years, the association for the 1960 birth cohort is only a 0.26 increase in years of schooling for adults whose parents separated.

Figure 6. Association between Education PGS and Educational Attainment by Childhood Family Structure across Birth Cohorts

Cohort change in the importance of genes for adults who experienced a parental death most closely resembles the trend for adults who lived with both parents until age 16, in line with our hypothesis 3a. The association between the education PGS and educational attainment is relatively stable across cohorts— approximately 0.46 years of schooling — and only moderately weaker than the association for adults from stable two parent households. In sum, this indicates that family instability and conflict mechanisms are most likely behind the decline in the importance of genes for education amongst adults who experienced a parental separation during childhood after the 1940 birth cohorts.

DISCUSSION

Our study on the intergenerational consequences of parental separation on children's chances to fulfil their genetic potential advances our understanding on the emergence of social inequality in several ways. As sociologists become increasingly interested in the role of genetics for the intergenerational transmission and children's life-course outcomes, only few consider genetic factors empirically. Moreover, we are only at the beginning of understanding the pivotal role of the environmental conditions for the realization of genetic influences for education, which is arguably one of the most important indicators for children's life chances due to its direct link to social mobility. Previous studies have either looked at parents' social standing to acknowledge social forces on the micro-level or changes across countries or over time acknowledging socio-historical context (Branigan et al. 2013; Conley et al. 2015; Engzell and Tropf 2019; Erola et al. 2021; Heath et al. 1985; Herd et al. 2019; Isunget et al. 2021; Lin 2020; Liu 2018; Silventoinen et al. 2020).

An important inequality generating mechanism however has often been neglected in the literature: childhood family structure. Western industrial democracies have all witnessed

dramatic shifts in family structure. Changes in the family context impose not only social risks for spouses, but also for their children. Our integrative study – combining sociology, demography, and genetics – based on molecular data using most recent education PGS (Lee et al. 2018) demonstrated that genetic factors play a smaller role for adults' educational attainment if they had experienced a parental separation or divorce during childhood compared to those who remained coupled in the United States. In addition, we found that the negative impact worsened over historical time. The magnitude of genetic influences on education declined across cohorts for those whose parents separated or divorced during childhood, while the impact of genes remained more or less stable among adults who grew up with parents that stayed together.

Our study also shed some light on the underlying mechanisms by including parental death next to stable two parent families as a second reference group for parental separation (Amato and Anthony 2014; Biblarz and Gottainer 2000). The trend in the importance of genetic factors for education over time was about the same for those who experienced a parental death during childhood and children whose parents stayed together. This suggests that the mechanisms that run through parental conflict and psychological stress as suggested by the family instability perspective as opposed to the lack of parental control and social networks as claimed by the parental absence perspective (Cavanagh and Fomby 2019). When we link these family dynamics – that also intensify to over time – to the well-established concept of enhancement, we find evidence that family stress and conflict prevent separated parents from providing enriched rearing conditions and tailored inputs that facilitate the realization of genetic potential for education. In addition, the direct experience of stress impedes children's development and may as well suppress the realization of genetic influences (Lupien et al. 2009).

Together the findings call for more generous institutionalized social protection to mitigate the adverse consequences linked to a divorce and separation. Social policies that

reduce future uncertainty, e.g. economic strain, are likely effective measures to reduce stress and potential conflict, and therefore protect children from negative spill-over effects. Such policy interventions are needed especially during separation and in the years that follow. However, there is an additional need for interventions across the process of separation, especially prior to separation, that help children to cope with stress and conflict in the parental home and build enhancing environments outside of the parental home. For instance, schools could offer or expand on targeted counselling for those that experience family conflict, provide after-school programs, and extra-curricular enrichment activities. Especially the latter – enriching environmental settings outside the family context – are important interventions, because they could compensate for the lack of tailored home environments that parents may not be able to provide across the process of separation.

While results on the underlying mechanisms support the family instability perspective, our evidence is nonetheless indirect and inferred through a comparison with parental death. This comparison may be criticized as there are distinct experiences linked to both a parental separation and the loss of a parent. However, in the context of our study, which investigated the intergenerational consequences of parental separation across the 20th Century, the comparison of adults who lost a parent is one of the most suitable strategies to approach the underlying mechanism for our birth cohorts. Given the stark similarity of adults who experienced a death and those who grew up in stable families it seems reasonable to locate the underlying mechanism in family conflict and associated stress as opposed to the lack of monitoring. Nonetheless, the mechanisms need further testing, ideally with items covering adverse family dynamics. Future studies should, for instance, analyse objective measures on family conflict, such as frequency and intensity of arguments, and how this is subjectively experienced by children. Moreover, direct of measures for stress, such as allostatic load, could provide valuable insights on the stress pathway. Specifically, prospectively collected data

would allow us identify when during the process of separation enhancement processes are suppressed. Knowledge about the timing would also help to design social policies most effectively.

There are additional limitations of our study. First, recall error may bias our results as we rely on retrospective life history data. Older respondents may not be able to remember their childhood circumstances well. While, we cannot rule out that some respondents may indeed have difficulties in remembering life events from their childhood, the question that we analyse asks broadly about whether parents separated or divorced before the age of 16. Given the severity of this family event, it seems fair to assume that they are able to provide valid information (Havari and Mazzonna 2015). Also, assuming that the likelihood of recall bias increases with age, it is important to note that a divorce was much more exceptional for older respondents and therefore more likely to be remembered.

Another age-related bias might be induced through mortality. For instance, individuals with higher education PGS also live longer and more likely to be in our sample. We address such selection by including longevity PGS in all our analysis to capture any bias induced by mortality. However, for our comparison to be affected by mortality bias, this selection process would need to differ by childhood family structure, which is unlikely to be the case.

Finally, despite the advanced molecular genetic methodological approach that we use in this study, we are not able to rule out bias related to rGE. While previous twin based research suggests that rGE are not the main driver of the intergenerational consequences (D’Onofrio et al. 2006; O’Connor et al. 2000), future studies using molecular approaches should account for such an bias. However, this requires information on parental genotypes, i.e., data on genotyped trios (mother, father, and child), which are very rare and restrictive in terms of data access.

Overall, our research shifts attention to an overlooked dimension of children's disadvantage and opens up routes for further research, specifically on heterogeneous effects. First, children's vulnerabilities may be age-dependent. Developmental theories propose that early childhood is the most vulnerable phase of children's lives, as children rely almost exclusively on the resources and stimuli provided by their parents. Therefore, the negative impact of parental divorce or separation on children's chances to realize their genetic potential for education may be largest during early childhood, a period marked by increased responsiveness to environmental conditions (Shonkoff and Phillips, 2000; Cunha and Heckman, 2007).

Second, there may be differences by gender. Previous research for the United States shows that the strength of genetic influences on education differed for men and women with cohort variation associated with changing educational opportunity structures (Branigan et al. 2013; Herd et al. 2019). Future research should therefore examine whether our findings on parental separation or divorce on children's chances to express their genetic potential differ by child's gender.

Third, a promising research area is to focus on circumstances where parental separation and divorce is beneficial for the realization of genetic potential for education. There are certainly incidences in which a break up lowers stress levels and may even help the custodial parent create an enhancing rearing environments. Relatedly, children's relationship to the non-custodial parents should also be taken into account in further research as a stable and good relationship may protect children as well from stress and buffer some of the adverse consequences. Overall, distinct family conditions linked to parental separation can diminish children's chances to tap their genetic potential for education. This implies a drastic waste of talent given the substantial proportion of children experiencing a parental break up during childhood.

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TABLES

Table 1: Sample Summary Statistics by Childhood Family Structure

	Separation	Death	Stable	Separation & Death	Other
Years of Education	13.190 (2.20)	13.191 (2.52)	14.075 (2.26)	13.060 (2.29)	14.014 (2.46)
Gender					
Men	43.680 (49.64)	46.849 (49.93)	42.138 (49.38)	39.266 (48.97)	43.401 (49.61)
Women	56.320 (49.64)	53.151 (49.93)	57.862 (49.38)	60.734 (48.97)	56.599 (49.61)
Birth Year	1949 (10.39)	1944 (10.18)	1947 (9.87)	1948 (10.42)	1943 (9.91)
Parental Education	11.994 (2.84)	11.500 (3.18)	12.172 (2.93)	11.818 (2.85)	12.381 (3.27)
Education PGS	-0.027 (0.97)	-0.011 (0.95)	0.061 (1.00)	-0.102 (0.97)	0.164 (1.03)
N	615	903	4260	187	519

Note: Average/percentages and standard deviations in parentheses displayed, not including imputed cases. Data are weighted.

FIGURES

Source: Adapted figure from Baier and Van Winkle (2020).

Figure 1. Conceptual Framework: Parental Separation as Moderator for Genetic Influences on Educational Attainment.

Figure 2. Educational Attainment by Childhood Family Structure across Birth Cohorts

Figure 3. Childhood Family Structure across Birth Cohorts

Figure 4. Distribution of Education PGS by Childhood Family Structure

Figure 5. Association between Education PGS and Educational Attainment by Childhood Family Structure

Figure 6. Association between Education PGS and Educational Attainment by Childhood Family Structure across Birth Cohorts

APPENDIX

Table A1. Results from OLS Linear Regressions of Years of Education on Education PGS, Childhood Family Structure, and Birth Cohort

	Model 1	Model 2
Education PGS	0.491*** (0.04)	0.513*** (0.07)
Gender (ref.: Men)		
Women	-0.219*** (0.06)	-0.217*** (0.06)
Family Structure (ref.: Two-Parent)		
Separation	-0.781*** (0.10)	-0.220 (0.23)
Death	-0.623*** (0.10)	-0.302+ (0.17)
Separation & Death	-0.790*** (0.17)	-0.652+ (0.36)
Other	-0.144 (0.12)	0.239 (0.22)
Family Structure*Education PGS		
Separation	-0.145 (0.10)	0.426* (0.20)
Death	-0.084 (0.09)	-0.063 (0.16)
Separation & Death	0.425** (0.15)	0.214 (0.31)
Other	0.117 (0.11)	0.122 (0.25)
Birth Year	0.020** (0.01)	0.033*** (0.01)
Birth Year (squared)	-0.000+ (0.00)	-0.001* (0.00)
Principle Components		
1	7.204* (3.23)	6.952* (3.24)
2	-10.460** (3.18)	-10.485*** (3.17)
3	-6.368* (3.23)	-6.691* (3.23)
4	-2.042 (3.14)	-2.347 (3.14)
5	-16.291*** (3.75)	-16.085*** (3.76)
6	1.949 (3.25)	2.297 (3.25)
7	-1.269 (3.17)	-0.825 (3.16)

8	-1.874 (3.11)	-2.001 (3.11)
9	-0.654 (3.12)	-0.750 (3.12)
10	2.252 (3.04)	2.362 (3.05)
Longevity PGS	-0.028 (0.03)	-0.027 (0.03)
Parental Education	0.293*** (0.01)	0.291*** (0.01)
Education PGS*Birth Year		-0.000 (0.01)
Education PGS*Birth Year (squared)		-0.000 (0.00)
Family Structure*Birth Year Separation		-0.055* (0.03)
Death		-0.042+ (0.02)
Separation & Death		0.038 (0.04)
Other		-0.048+ (0.03)
Family Structure*Birth Year (squared)		
Separation		0.001 (0.00)
Death		0.001 (0.00)
Separation & Death		-0.002 (0.00)
Other		0.001 (0.00)
Family Structure*Education PGS*Birth Year		
Separation		-0.073** (0.03)
Death		0.009 (0.02)
Separation & Death		0.003 (0.04)
Other		0.005 (0.03)
Family Structure*Education PGS*Birth Year (squared)		
Separation		0.002* (0.00)
Death		-0.001

		(0.00)
Separation & Death		0.000
		(0.00)
Other		0.000
		(0.00)
Constant	10.442***	10.318***
N	6,661	6,661

Note: Unstandardized coefficients (log odds) and standard errors in parentheses displayed. Significance denoted + p<0.10, * p<0.05, ** p<0.01, and *** p<0.001. Birth year centred at 1930. Data are weighted.

NOTES

ⁱ SNPs are DNA nucleotide pairs that vary within a population. For example, at a single position in the genome some individuals may have the nucleotide cytosine, while others have thymine. The variants of each SNP are called alleles and the alleles that are the second most common in a population are termed minor alleles. For detailed information on the collection and preparation on the genotypic data, see the Quality Control Report for Genotypic Data at http://hrsonline.isr.umich.edu/sitedocs/genetics/HRS2_qc_report_SEPT2013.pdf prepared by the University of Washington.