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Paternal antisocial behavior and offspring cognitive ability: a population-based quasi-experimental study

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Abstract

Parents' antisocial behavior is associated with developmental risks for the offspring but effects on cognitive ability are unknown. We used linked Swedish register data for a large sample of adolescent men (N = 1,177,173) and their parents to estimate associations between fathers' criminal convictions and sons' cognitive ability assessed at compulsory military conscription. Mechanisms behind the association were tested in children-of-siblings models across three types of sibling fathers (half-siblings, full-siblings, and monozygotic twins) with increasing genetic relatedness, and in quantitative genetic models. Fathers' convictions associated with lower cognitive ability in sons (any crime: Cohen's d = -.28; violent crimes: Cohen's d = -.49). Adjusting for more genetic factors gradually reduced and eventually eliminated the association. Nuclear family environmental factors did not contribute to the association. Our results suggest that the association between paternal antisocial behavior and offspring cognitive ability is not causal but mostly due to underlying genetic factors.

(149/150 words)

Keywords

antisocial behavior, cognitive ability, parents, offspring, quasi-experimental designs, genetic confounding

Introduction

Antisocial behavior is a major societal, public health and safety concern, associated with substantial hardships for families. Intergenerational research indicates that children of antisocial parents are at elevated risk for negative outcomes including conduct disturbance (Hicks, Foster, Iacono, & McGue, 2013; Thornberry, Freeman-Gallant. Lizotte, Krohn, & Smith, 2003), criminality (Frisell, Lichtenstein, & Långström, 2011), psychiatric disorders (Herndon & Iacono, 2005), substance use, and low academic achievement (Murray, Loeber, & Pardini, 2012). Despite this literature and the large numbers of families affected by parental antisocial behavior, surprisingly little is known about how parents' antisocial behaviors are associated with psychological and cognitive development in the offspring. Cognitive ability predicts socioeconomic success, health and mortality (Calvin et al, 2011; Strenze, 2007), and is also one of the best-replicated individual contributors to the risk for antisocial behavior (Portnoy, Chen, & Raine, 2013). Assessing the link between parental antisocial behavior and offspring cognitive ability is thus important for our understanding of the intergenerational continuity of antisocial behavior and related risks.

Children of antisocial parents may experience various adversities which could compromise their cognitive development. Such factors include unstable rearing environments, poor parenting practices, limited cognitive stimulation, inter-parental conflict and violence, and even victimization from parental abuse or neglect (Eaves, Prom, & Silberg, 2010; Hanscombe, Haworth, Davis, Jaffee, & Plomin, 2011; Koenen, Moffitt, Caspi, Taylor, & Purcell, 2003; Perkins & Graham-Bermann, 2012; Schwartz & Beaver, 2013). Adversities might influence cognitive development directly or their effects could be mediated via other factors such as the biological effects of chronic stress. For example, it has been suggested that violence exposure—a factor potentially linked to parents' antisocial behaviors and criminality—can cause neurocognitive problems in children via neurological changes directly resulting from the exposure, or via problems in interpersonal communication between parents and children (Perkins & Graham-Bermann, 2012). On the other hand, it has been speculated that parental involvement in the criminal justice system itself might also have adverse effects on children's development (Murray et al., 2012).

However, antisocial behavior is not randomly distributed in the population. Antisocial parents are likely to differ from parents without a liability to antisocial behavior also in many important aspects which could influence offspring cognitive development. Antisocial behaviors are more common among parents with low educational and socioeconomic levels, which are associated with poorer cognitive development in the offspring (Lawlor et al., 2005; Neiss & Rowe, 2000). As a result, any association between parental antisocial traits and offspring cognitive development could be non-causal and merely reflect confounding by factors such as parental cognitive abilities or genetic influences. It is well-known that antisocial behaviors and cognitive abilities are significantly heritable, genetic factors explaining 40-70% of their variation in the population (Burt, 2009; Frisell, Pawitan, Långström, & Lichtenstein, 2012; Haworth et al., 2010; Rhee & Waldman, 2002). Antisocial traits and cognitive abilities are also systematically negatively correlated (Frisell, Pawitan, & Långström, 2012; Isen, 2010), and twin studies have suggested this correlation to be in part due to common genetic influences (Koenen, Caspi, Moffitt, Rijsdijk, & Taylor, 2006). However, a meta-analysis of large-scale twin studies of cognitive ability confirmed that in addition to genetic influences, environmental factors shared by co-twins reared together explain a significant proportion of variation in cognitive development until young adulthood (Haworth et al., 2010). Thus, an association between parents' antisocial behavior and cognitive outcomes in the offspring might arise due to genetic confounding but it could also reflect a true causal influence of parental behavior.

Commonly used observational research designs which employ data collected from unrelated individuals and their parents can show an association between parental and offspring traits but are unable to clarify the mechanisms behind the intergenerational association. In contrast, family-based quasi-experimental study designs, such as sibling comparison and children-of-siblings designs can be used to rigorously test for causal effects of the family environment and parental characteristics (D'Onofrio, Lahey, Turkheimer, & Lichtenstein, 2013; Rutter, Pickles, Murray, & Eaves, 2001). Such family-based, quasi-experimental designs compare biologically related individuals who differ with regard to a risk factor, such as parental antisocial behavior, and are thus able to partly control for unmeasured genetic and environmental factors shared by family members. The potential of quasi-experimental methods for testing causal hypotheses has been stressed but, so far, they have only rarely been applied to testing environmental influences on traits such as cognitive ability (D'Onofrio et al., 2014; Ellingson, Goodnight, Van Hulle, Waldman, & D'Onofrio, 2014; Lundberg et al., 2010).

To our knowledge, two previous quasi-experimental studies on the effects of parental antisocial traits on offspring behavioral characteristics have been published (D'Onofrio et al., 2007; Silberg, Maes, & Eaves, 2012). Both studies employed the Children of Twins (CoT) design in which offspring of monozygotic (MZ) and dizygotic (DZ) twin parents discordant for antisocial traits were compared. D'Onofrio et al. (2007) focused on the intergenerational transmission of childhood conduct problems and found evidence for an environmentally mediated, and possibly causal, association for male offspring whereas genetic risk explained the intergenerational association for female offspring. Silberg et al. (2012) used an extended CoT design and found that the links between parental antisocial behavior and different offspring behavioral outcomes (i.e., hyperactivity, conduct disturbance, and depression) were explained by different combinations of genetic and family environmental factors. However, neither of these studies included offspring cognitive ability.

We used a large population-based dataset including Swedish men born across 40 years and their parents to estimate associations between fathers' antisocial behavior and their sons' cognitive ability. To test for potential genetic confounding, the association between fathers' antisocial behavior and offspring cognitive ability was studied within offspring of sibling fathers discordant for criminal convictions and compared across three sibling types in the parent generation (i.e., half-siblings, full-siblings, and MZ twins) which differ in their degree of genetic relatedness. Sources of familial confounding were further investigated with quantitative genetic structural equation modeling (SEM) in extended family pedigrees.

Method

Databases

We performed a national cohort study by linking several Swedish longitudinal population-based registries maintained by governmental agencies, with data available until the end of 2009. The study was approved by the institutional review board of the Karolinska Institutet. A unique personal identification number, given to all Swedish citizens at birth and to immigrants upon arrival to Sweden, was used as key in the register linkages. Cognitive ability test data were obtained for males born in Sweden 1952-1991 from the Conscript Register. Conscription at age 18 was mandatory for all Swedish men until 2009, absence being punishable. More than 95% of men generally attended the conscription testing, exemptions were due to somatic disorders or handicaps, or mental retardation (Carlstedt, 2000).

Parents' antisocial behavior was indexed by criminal convictions obtained from the Crime Register, which contains all convictions in lower courts for individuals aged 15 (age of criminal responsibility) and older from 1973 onwards. Detailed information about the timing, nature, and number of offenses leading to court convictions are included in the register. The Multi-Generation Register (MGR; Statistics Sweden, 2010) identifies biological and adoptive parents of each individual born since 1932 and living in Sweden at any time since 1961. The MGR linkages were used to identify biological parents of conscripted men and to construct extended family pedigrees for the children-of-siblings analyses by identifying paternal grandparents. The Swedish Twin Register was used to identify pairs of fathers who were MZ or DZ twins. The Total Population Register provided information about the parents' country of birth. Dates for parents' death and emigration out of Sweden were obtained from the Cause of Death Register and the Migration Register, respectively. Both parents' highest educational level was available from the National Census in 1970 and from the Education Register since 1985. Information on parents' hospitalization due to psychiatric disorders was obtained from the Hospital Discharge Register which contains details of all individual episodes of hospitalization in Sweden since 1973. Data on socioeconomic status during childhood were available from National Censuses in 1960, 1970, 1980, 1985 and 1990.

Study population

We identified all men born in Sweden between 1952 and 1991 (N = 2,207,631). Men with missing conscription information (N = 385,964), missing value for the IQ variable (N = 88,924), and missing information on biological father's or mother's identity (N = 24,586) were excluded. We also excluded all offspring who had been adopted (N = 13,257). To make the samples used in population analyses and within-family analyses (see below) consistent, we excluded individuals whose parents were born before 1932 (N = 502,834). Offspring whose parents died or emigrated out of Sweden before the start of the Crime Register in 1973 were also excluded (N = 14,893). After exclusions, the population analyses included

1,177,173 men with cognitive ability data. For the within-family analyses, 111,784 extended families with paternal cousins were identified, randomly selecting one son per nuclear family. There were 102,133 pairs of full sibling fathers (full brothers or DZ twins [N = 1,003]), 8,977 pairs of half-sibling fathers, and 674 pairs of MZ twin fathers. For the quantitative genetic SEM, data from all families were used selecting a maximum of two brothers per nuclear family (N = 867,439).

Measures

Parental criminal convictions were classified into subtypes of non-sexual violent, sexual, drug-related, property-related and traffic-related crimes. *Violent crimes* included convictions of murder, manslaughter, assault, kidnapping, illegal restraint, illegal coercion or threats, robbery, threats or violence against an officer, arson, gross violation of a person's integrity, and harassment. *Sexual crimes* included rape, sexual coercion, child molestation, sexual intercourse with a child, child pornography offenses, pimping and sexual harassment. *Drug-related crimes* were convictions of possession of substances for personal use, supply, manufacture, and consumption, and crimes committed while driving under the influence of alcohol or other substance. *Property crimes* included convictions such as theft, larceny, burglary, embezzlement and vandalism. *Traffic crimes* included, for example, crimes against road safety, and unlawful driving of a vehicle, but excluded speeding tickets. *Any crime* was defined as any conviction amongst the subtypes listed above. Attempted and aggravated forms of the respective offenses were included whenever applicable.

General cognitive ability was assessed with the Swedish Enlistment Battery (SEB), administered as part of the military conscription testing. Three different versions of the SEB were used during the 40-year period for which cognitive data were available: the SEB67 during the years 1970-1979, the SEB80 during 1980-1993, and the CAT-SEB for 1994-2009

(Carlstedt, 2000). The SEB67 and SEB80 were paper and pencil tests with four subtests assessing verbal, visuospatial, technical and inductive abilities, all summed to derive a general cognitive ability measure. High internal consistency has been reported for the SEB80 (coefficient alpha = .79 - .91) (Carlstedt & Mårdberg, 1993). Due to theoretical and methodological developments in intelligence research and the advent of the personal computer, a new version of the SEB (CAT-SEB), utilizing computer-aided testing, was launched in 1994. The CAT-SEB was based on a three-level hierarchical model of cognitive abilities, and included 12 tests, 10 of which were used to form a latent general cognitive ability factor and the secondary factors for crystallized intelligence and general visualization. The reliability of the CAT-SEB tests is also good (coefficient alpha = .70 - .85) (Mårdberg & Carlstedt, 1998). The general cognitive ability variable, available from the Conscription Register and based on the described SEB versions, is presented on a stanine scale as a normally distributed variable divided into nine categories with a mean of 5 and a standard deviation of 2. The scale was standardized separately for each year of conscripts, resulting in a constant distribution across the study period.

Potential parental confounding factors included as covariates were birth year, immigrant status, highest educational level, and lifetime history of hospitalization due to any psychiatric disorder (ICD8: 290–315, ICD9: 290-319, and ICD10: F00-F99) for both parents. Immigration was coded as a dichotomous variable denoting whether the parent was born outside of Sweden. Educational level at age 30 or older was assessed with an ordinal variable with seven categories, ranging from less than the 9 years' compulsory schooling to postgraduate education. Father's cognitive ability was included as a covariate in analyses on a sub-sample of sons whose fathers were born in 1952 or later and had cognitive ability data available from the Conscription Register (N = 287,966).

Offspring covariates included birth year and family socioeconomic status (SES) before age 10 years. The SES variable available from the censuses was derived from the occupation of the head of the household (usually the father) and coded into three classes: low (skilled and unskilled workers across all fields), medium (low- and intermediate-position white collar workers) and high (high-position white collar workers and self-employed professionals and entrepreneurs). For the cohort of sons born in 1991 (N = 16,595), the SES variable denoted household SES during the year preceding the son's birth.

Statistical analysis

Due to the significantly higher prevalence of crime among men compared to women, we focused on fathers' criminality, including mothers' convictions as a covariate. Associations between fathers' criminal convictions and sons' cognitive ability were first studied in the full population sample using linear regression models with adjustment of standard errors for the non-independence of brothers in the offspring generation using a robust sandwich estimator. Four different models were fitted: Model 1 made no adjustments; Model 2 adjusted for fathers' and sons' birth year, family SES and father's educational level; Model 3 added mother's birth year, criminal convictions and educational level as covariates; and Model 4 further adjusted for parents' psychiatric hospitalization and immigration status. The population regression models were conducted separately for the different crime subtypes and for any crime. To account for confounding by father's cognitive ability, separate analyses were conducted for the subset of sons whose fathers had cognitive ability data available. In these models, fathers' cognitive ability was used instead of educational level.

Conditional linear regression models (i.e., fixed-effects regression models) (Gunasekara, Richardson, Carter, & Blakely, 2014) were fitted to study the association between fathers' convictions and sons' cognitive ability within sibling father pairs using the *xtreg* modeling command with the fixed effects (*fe*) option in Stata 12 (StataCorp, 2011). These models use a within estimator to compare the cognitive ability score of cousins discordant for father's criminality, and thus adjust for all unmeasured factors shared by cousins. Models were fitted separately to data from the three different types of sibling fathers identified from the MGR: half-siblings who share, on average, 25% of their segregating genes, full-siblings and DZ twins who share 50% of their genetic makeup, and MZ twins who share 100% of their genes. Hence, these within-family analyses increasingly control for genetic confounding in the association between father's criminality and offspring cognitive ability. Consequently, if genetic factors confounded the association, a reduced regression coefficient should be observed in each analysis adjusting for more genetic factors (i.e., coefficient in the population > offspring of half-siblings > offspring of full-siblings > offspring of MZ twins). In contrast, a causal effect of father's criminality would be supported by the observation of an equal association across the population-based and within-family models.

To complement the within-family regression analyses, a quantitative genetic SEM (Kuja-Halkola, D'Onofrio, Larsson, & Lichtenstein, 2014) was conducted in the extended family pedigree data in order to estimate the magnitudes of genetic and environmental sources of familial confounding. The model is an extension of the standard model used in twin research, which decomposes variance into genetic influences (*A*), shared environmental (*C*) and non-shared environmental (*E*) influences. In contrast to the standard twin model, the present model estimates an intergenerational bivariate association between fathers' crime and sons' cognitive ability and decomposes the shared environmental variance into environmental influences shared by all members of an extended family (i.e., fathers who are full siblings, MZ twins, or maternal half-siblings, and their sons) (*Cf*) and into environmental influences only shared by members of a nuclear family (i.e., father and his son(s)) (*C*). The model partitions the association between paternal crime and offspring cognitive ability into the *A*, *Cf* and *C* factors and estimates the proportion of the correlation explained by each factor. The model has been described in detail elsewhere (Kuja-Halkola et al., 2014). The OpenMx package (Boker et al., 2011) in the software R (R Development Core Team, 2012) was used for modeling.

Several sensitivity analyses were conducted to rule out possible alternative explanations for our results. First, to rule out the effect of different likelihood of having convictions in the Crime Register depending on the birth year of the father (i.e., left-truncation), the association was studied by stratifying the sample into quartiles of father's birth year distribution. Second, to inspect potential effects of the differences between the CAT-SEB and the earlier paper and pencil cognitive batteries (SEB67 and SEB80), the association was estimated separately for men assessed with these two methods. Third, while any convictions regardless of their timing were included in the main analysis, a sensitivity analysis was conducted including only paternal convictions which took place between the son's birth and conscription. Finally, to further evaluate the plausibility of possible genetic confounding in the intergenerational association between fathers' crime and offspring cognitive ability, we conducted within-family analyses switching the variables for fathers and sons, i.e., testing the association between father's cognitive ability and son's criminal convictions in the population and across different types of sibling pairs in the father generation.

Results

As shown in Table 1, men whose fathers had been convicted of any crime had lower cognitive ability scores compared to men whose fathers had no criminal convictions (4.70 [95% CI: 4.69-4.70] *vs.* 5.22 [5.22-5.23], Cohen's $d = -.28$). Of the subtypes of paternal convictions, violent and sexual crimes were associated with lowest cognitive ability among sons (4.28 [95% CI: 4.26-4.30] and 4.32 [4.27-4.38], respectively) whereas the association was weakest for traffic crimes (4.73 [4.72-4.74]). Similar mean differences were observed for paternal cognitive ability among the subset of fathers who had cognitive ability data available (N = 223,433 fathers). Fathers' criminality was also associated with lower parental education, higher prevalence of psychiatric morbidity, having been born outside Sweden, lower socioeconomic status when the son was below age 10, and mothers' criminal convictions (Table 1).

Results from regression models of sons' cognitive ability regressed on fathers' conviction subtypes in the population and in the subsample of fathers with cognitive ability measures are presented in Table 2. In unadjusted models, fathers' criminal convictions were associated with a .43 to .86 stanine-units lower cognitive ability score in the offspring. For all crime types, adjustment for cohort effects, family SES and paternal education significantly reduced the association (by 41% to 47%, Model 2). Adjustments for mothers' characteristics (Model 3), parental immigrant status and lifetime psychiatric morbidity reduced the associations further (by 59% to 63% in total, Model 4) but did not completely eliminate them.

To investigate the mechanisms linking fathers' any criminal convictions and sons' cognitive ability, the association was compared in the population and across fathers who were half-siblings, full-siblings and MZ twins. As shown in Table 3, a gradually reduced association was found with increasing adjustment for unmeasured genetic factors (Model 1, regression coefficient in the population: -.53 [95% CI: -.54; -.52], in sons of half-siblings: -.38 [-.46; -.29], in sons of full-siblings: -.22 [-.25; -.19], in sons of MZ twins: .14 [-.18; .46]). The pattern of associations remained similar when adjusting for measured parental covariates (Models 2-4). Potentially due to less statistical power for estimation among offspring of half-siblings after adjustments, overlapping confidence intervals for regression coefficients in this group with estimates from the population and offspring of full-siblings were observed.

However, the estimates for sons of full-siblings and sons of MZ twins were smaller than the population estimates (Table 3). Models adjusting for father's cognitive ability instead of education had reduced power due to limited sample sizes, but provided similar results; although the associations within sons of half-sibling pairs and sons of MZ twins could not be differentiated from other groups, the associations within sons of full-siblings were consistently smaller than the population estimate (Supplementary table 1). A similar pattern of associations with indications of genetic confounding of the association between paternal criminality and offspring cognitive ability was found for the different subtypes of crimes in the full sample (Supplementary table 2).

Results of the quantitative genetic model strongly supported the children-of-siblings regressions (Supplementary tables 3-5). Based on the model, genetic factors explained 82% of the intergenerational association between fathers'any crime and sons' cognitive ability. The rest of the association was due to environmental factors shared by all members of an extended family (*Cf*), whereas nuclear family environmental influences (*C*) did not contribute to the association.

Sensitivity analyses indicated that the association between any criminal convictions in fathers and sons' cognitive ability was similar across quartiles of fathers' birth year distribution, with only the oldest cohorts having a slightly reduced association (regression coefficient for fathers born before 1940: -.46 [95% CI: -.48; -.44], 1940-1945: -.52 [-.54; -.50], 1946-1951: -.52 [-.53; -.50], and finally for fathers born after 1951: -.51 [-.53; -.49]). The association was also similar among men whose cognitive ability had been assessed with a paper and pencil test as compared to the newer computerized test (regression coefficient for SEB67 and SEB80: -.51 [95% CI: -.53; -.50], for CAT-SEB: -.54 [-.55; -.53]). Restricting the analyses to only include paternal convictions taking place between the son's birth and conscription suggested a somewhat stronger association with son's cognitive ability (unadjusted regression coefficient: -.62 [95% CI: -.63; -.61]) compared to the main analysis but the association was similarly reduced in within-family comparisons (Supplementary table 6).

Finally, to test the robustness of the finding that adjusting for more genetic factors reduced the association between fathers' criminality and son's' cognitive ability, we conducted similar population and children-of-siblings analyses on the association between paternal cognitive ability and any criminal convictions in sons. The rationale for this was that if genetic factors play a role in the intergenerational association between criminality and cognitive ability, a similar pattern of results should be seen when predicting sons' criminality from their fathers' cognitive functioning. The results were compatible with this interpretation. Conditional logistic regression analyses with population data of sons' convictions on fathers' cognitive ability, adjusting for fathers' convictions, found each 1-unit increase in paternal cognitive ability on the stanine scale to be associated with a 13% reduction in the likelihood of offspring criminal convictions (odds ratio, OR =.87 [95% CI: .87-.88]). In contrast, a gradually reduced association was found in children-of-siblings analyses when genetic factors were controlled for more extensively (sons of half-siblings OR=.86 [.80-.92], sons of full-siblings OR=.93 [.90-.96], sons of MZ twins OR=1.12 [.70-1.79]).

Discussion

In a nationwide population-based sample of more than 1 million adolescent men, we found a robust association between paternal antisocial behavior and offspring cognitive ability. Adolescents whose fathers had criminal convictions performed poorer in the cognitive testing during compulsory military conscription than did those whose fathers had not been convicted, suggesting that in addition to risks related to adverse behavioral (Hicks et al., 2013; Thornberry et al., 2003) and psychiatric outcomes (Herndon & Iacono, 2005), offspring of antisocial parents are at risk for poor cognitive development. The association was observed for all crime types but it was strongest for fathers' violent crimes (Cohen's *d* = -.49) and weakest for traffic-related crimes (Cohen's *d* = -.26). To explicitly test whether genetic factors were important for the observed association, we conducted children-of-siblings analyses across three types of sibling father pairs differing in the degree of control for genetic confounding. These within-family analyses found that as more genetic factors were controlled for, the association between fathers' criminality and sons' cognitive ability was gradually diminished. When genetic factors confounding the association were completely adjusted for in sons of MZ twin brothers, no association between fathers' convictions and sons' cognitive ability was observed. This analysis was followed up with quantitative genetic modeling in the extended family data with results supporting the main analysis: genetic influences explained most of the association. Extended family environmental factors also contributed to the association but nuclear family environmental factors shared only between fathers and sons did not. Our findings are, hence, not supportive of a causal effect but rather suggest that genetic effects and non-genetic factors shared by members of extended families and potentially reflecting wider socioeconomic differences are sufficient to explain the intergenerational link between parents' antisocial behavior and lower cognitive ability in the offspring.

Previous research on parental antisocial behavior and offspring cognitive ability is scarce. A study among 3,000 urban American children found that paternal incarceration was associated with lower verbal ability in children at age 5, but adjustment for a range of paternal and maternal covariates including cognitive ability and educational level completely eliminated the association (Geller, Cooper, Garfinkel, Schwartz-Soicher, & Mincy, 2012). Our findings are compatible with previous twin and family studies suggesting that the link between antisocial traits and lower cognitive ability is in part explained by genetic factors (Frisell et al., 2012; Koenen et al., 2006). Our results thus indicate that despite the adversities related to parental criminality, having a father who has been convicted of crime is unlikely to influence cognitive development in the offspring when the effects of other factors associated with parental antisocial behavior, including genetic risks, are taken into account. To confirm this finding, we also investigated whether genetic factors explained the association between fathers' cognitive ability and sons' risk for criminal convictions. This analysis provided additional support for genetic confounding in the intergenerational association between antisocial behavior and cognitive ability.

To gain a comprehensive view of parental antisocial behaviors, we investigated five crime subtypes. Violence is the most severe form of antisocial behavior, and fathers' violent crimes were associated with lowest cognitive ability scores both among fathers and sons. This result is compatible with earlier studies suggesting lower verbal cognitive ability among violent compared to non-violent antisocial individuals (Barker et al., 2007; Kennedy, Burnett, & Edmonds, 2011). Our results suggest that the intergenerational association between antisocial behavior and cognitive ability is stronger for more severe crimes than for less severe crimes, such as traffic offenses. However, similar evidence for genetic confounding emerged regardless of the subtype of father's crime, suggesting that the genetic overlap with cognitive ability is not crime-specific but rather related to criminal behavior more generally.

Several methodological considerations are relevant for the interpretation of these results. First, because representative cognitive data were only available for men, our findings do not necessarily generalize to women. Second, official records of criminal convictions were utilized to index parental antisocial behavior, which may have biased the results. While the differential detection hypothesis states that criminals with lower cognitive ability are more likely to be arrested and convicted, and do not represent the population of all criminals, there is some evidence that both officially recorded and self-reported crimes are similarly associated with lower cognitive ability (Moffitt & Silva, 1988). Our register-based data did not include self-reported criminality, but adjustment for fathers' cognitive ability did not eliminate the association between fathers' convictions and son's' cognitive ability suggesting that differential detection of fathers with lower cognitive ability does not explain our results. Third, due to left-truncation of criminal register information, parent cohorts differed in their likelihood of having registered convictions. To overcome this bias, our analyses adjusted for both parents' birth year, and further analyses stratified the sample by fathers' birth year. Fourth, like all research using cognitive ability tests, our results may have been affected by differences in non-cognitive factors affecting performance such as test motivation and effort (Duckworth, Quinn, Lynam, Loeber, & Stouthamer-Loeber, 2011). However, in contrast to low-stakes research settings, performance in the conscription testing has clear and tangible consequences for the test takers, which is likely to reduce confounding by test motivation. Available evidence suggests that the association between cognitive ability test scores and antisocial behavior may be inflated but is not completely explained by differences in motivation (Duckworth et al., 2011; Lynam, Moffitt, & Stouthamer-Loeber, 1993). Finally, it should be noted that the children-of-siblings design, like any non-experimental research design, cannot conclusively prove or rule out a causal association. Each quasi-experimental design makes assumptions which need to be carefully considered when interpreting the results (D'Onofrio et al., 2013). Among the assumptions of the children-of-siblings analyses are that there are no carry-over effects, meaning that the exposure of one cousin has no effect on the outcome of the other cousin, and that the results generalize to extended families with no cousins. Our results were supported by compatible findings from a quantitative genetic SEM, in which data from all families were used.

In conclusion, our findings from a large and representative nationwide cohort of men suggest that parental antisocial behaviors are associated with lower cognitive ability in the offspring. However, children-of-siblings analyses and quantitative genetic modeling indicated that the association between paternal antisocial behavior and offspring cognitive ability is unlikely to be causal and rather reflects confounding by genetic and extended family influences. Our results suggest that poorer cognitive ability is one of the factors associated with the inherited risk for antisocial behavior.

Author Contributions

All authors contributed to planning of the study and interpretation of the results. AL performed the main analyses and drafted the manuscript. RK-H managed the creation of extended family pedigrees and conducted SEMs. All authors contributed to revising the manuscript and have accepted the final version.

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Declaration of Conflicting Interests

None declared.

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