A Prospective Investigation of Neurodevelopmental Risk Factors for Adult Antisocial Behavior
Combining Official Arrest Records and Self-reports

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Abstract

Neurodevelopmental deficits are postulated to play an important role in the etiology of persistent antisocial behavior (ASB). Yet it remains uncertain as to which particular deficits are most closely associated with ASB. We seek to advance this understanding using prospectively collected data from a birth cohort in which multiple indices of neurodevelopmental functioning and ASB were assessed. Participants ($n=2,776$) were members of the Providence, Rhode Island cohort of the Collaborative Perinatal Project. Information on demographic and neurodevelopmental variables was collected from pregnancy through age 7. When all offspring had reached 33 years of age an adult criminal record check was conducted. A subset of subjects also self-reported on their engagement in serious ASB. Bivariate logistic regression was used to examine the relationship between each neurodevelopmental factor and adult ASB and test whether associations varied depending on how ASB was ascertained. After controlling for background and contextual characteristics, maternal smoking during pregnancy, lower childhood verbal and performance IQ, and age 7 aggressive/impulsive behavior all significantly increased the odds of adult ASB. Associations were not modified by sex and did not depend on how ASB was assessed. However, while both males and Black participants were more likely to engage in ASB than their respective female and White counterparts, relationships were significantly stronger for official records than for self-reports. Results point to a particular subset of early neurodevelopmental risks for antisocial outcomes in adulthood. Findings also suggest that prior contradictory results are not due to the use of official records versus self-reported outcomes.

Keywords: neurodevelopmental deficits; antisocial behavior; prospective cohort study

Early neurodevelopmental deficits have been postulated to play an important role in the initiation and maintenance of persistent antisocial behavior (ASB) into adulthood (Moffitt, 1993). Factors from the prenatal period to early childhood have been investigated, including maternal smoking during pregnancy (D'Onofrio et al., 2010; Paradis et al., 2011; Wakschlag et al., 2002), pregnancy/delivery complications (PDCs) (Arseneault et al., 2002; Hodgins et al., 2001; Murray et al., 2010; Raine et al., 1997), low birth weight (Hack et al., 2004; Murray et al., 2010; Tibbetts and Piquero, 1999; Vaske et al., 2015), aggressive and impulsive behavior (Caspi, 2000; Dubow et al., 2014; Farrington, 1995), and indices of cognitive functioning such as IQ (Dubow et al., 2014; Raine et al., 2005; Sampson and Laub, 1993). Although some factors have shown robust associations with antisocial outcomes (e.g., lower verbal IQ), support for other early neurodevelopmental deficits (e.g., PDCs, low birth weight) has been equivocal. Identifying the neurodevelopmental factors most closely associated with persistent ASB is necessary to enhance our understanding of the etiology of such behavior.

To further our knowledge of the possible neurodevelopmental underpinnings of ASB, it is important to consider how methodological variations across studies may impact observed associations, including differences in outcome assessment. Adult ASB is frequently assessed using either official arrest records or self-reports of engagement in such behavior. Some researchers have suggested that differences in the measurement of ASB across investigations may (partially) explain previous inconsistent findings of the relationship between risk factors, including indices of neurodevelopmental functioning, and antisocial outcomes (Arseneault et al., 2002; Kirk, 2006; Maxfield et al., 2000; Moffitt et al., 1994; Moffitt and Silva, 1988). For instance, it is well-established that official records underestimate criminal activity since only a small fraction of criminal behavior comes to the attention of law enforcement, police use

discretion in deciding who to arrest, and not all arrests are officially recorded (Blumstein et al., 1986; Worden and Myers, 1999). Furthermore, not all types of ASB are criminal in nature. It is therefore possible that the relationships between particular neurodevelopmental deficits and adult ASB have been underestimated in studies using official records. Biases in self-reports have also been noted; the potential for significant under-reporting of ASB as well as over-reporting in particular subgroups has been documented (Kirk, 2006; Maxfield et al., 2000). However, researchers have rarely examined how measurement of ASB may impact observed associations between neurodevelopmental deficits and antisocial outcomes.

Other methodological variations have been cited as potential explanations for discrepant results. For example, it has been suggested that differences in how information on neurodevelopmental deficits is collected (e.g., prospective vs. retrospective reports) may influence findings (Arseneault et al., 2002). Aggregating different types of antisocial problems (e.g., violent and nonviolent behaviors) into a single outcome may also possibly attenuate or mask meaningful associations (Barker et al., 2007). In some studies, neurodevelopmental factors have been found to be predictive of only those subtypes of ASB characterized by violence and aggression (Raine et al., 1994).

Finally, many previous investigations examining associations between indices of neurodevelopmental functioning and ASB have focused exclusively on males. **Studies that have included both sexes have sometimes found evidence that the association between neurodevelopmental factors and ASB is stronger for males than females (e.g., Murray et al., 2010; Wakschlag et al., 2002).** Yet further investigations of large mixed sex samples are needed to determine whether sex modifies the relationship between compromised

neurodevelopmental functioning and ASB, or whether neurodevelopmental deficits play a similar role in the initiation and maintenance of behavior problems in both females and males.

Current Study

Our major objective was to advance the understanding of the true impact of deficits in early neurodevelopmental functioning on adult ASB. To this end, we were particularly interested in whether inferences differed depending on whether adult ASB was defined based on official arrest records or self-reported engagement in serious ASB. We also tested whether associations were stronger for violent versus nonviolent behavior and examined possible sex differences. An additional strength of the current research is that all data on neurodevelopmental characteristics were collected prospectively using valid and reliable methods. Unlike many previous studies following subjects only through childhood or adolescence, we were able to trace the impact of multiple indices of neurodevelopmental functioning on antisocial outcomes into adulthood.

Methods

Participants

Participants were offspring of mothers enrolled in the Providence, Rhode Island site of the Collaborative Perinatal Project (CPP) (Niswander and Gordon, 1972). The CPP was a multicenter study of pre- and perinatal antecedents of childhood mental, neurological, and physical abilities. Over 50,000 pregnancies were enrolled between 1959 and 1966 at several affiliated medical schools throughout the U.S. In Providence, approximately 50% of obstetric patients at participating hospitals were randomly selected for inclusion in the study and a total of 4,140 pregnancies were enrolled. Extensive obstetric, neurologic, psychologic, and

sociodemographic information from the perinatal period through age 7 was collected prospectively using standardized procedures.

Of the survivors from the original cohort, 81.9% ($n=3,138$) completed the age 7 assessment. (See Figure 1.) Somewhat more Black (87.6%) as compared to White (80.6%) participants completed the evaluation, but the difference was not substantial. Those seen at age 7 were comparable to those not assessed on other key background factors and putative neurodevelopmental risks. The current study is limited to the 2,776 Black and White participants who completed this assessment and had complete covariate information. (Because of the heterogeneity and small number of non-Black minorities these individuals were excluded.) Most subjects excluded from the analysis were omitted due to missing data on childhood socioeconomic status (SES). Excluded participants ($n=362$) were not found to significantly differ from those who were included on background characteristics, such as sex and SES, and neurodevelopmental factors, including maternal smoking during pregnancy and PDCs.

{Insert Figure 1}

In 1999-2000, an adult criminal history record check was performed in Rhode Island for each known surviving member of the sample (mean age=37, range=33-40). A subset of these subjects also participated in adult follow-up studies, occurring when subjects were ages 30-42 (Buka et al., 1998; Gilman et al., 2008; Kahler et al., 2008), and self-reported on their engagement in ASB during standardized structured clinical interviews. All participants had valid outcome information on adult ASB from at least one data source: 1,848 had information from official arrest records only; an additional 928 subjects also provided self-reports during the follow-up interviews. Institutional review boards at Brown and Harvard Universities approved the follow-up studies and written informed consent was provided by participants.

Measures

Background characteristics. The sex distribution of the sample was roughly equal (49.3% male) and the majority of subjects were White (77.6% White, 22.4% Black). Data on sociodemographic characteristics were collected at the first prenatal visit and reassessed when the children were age 7. An index of SES was calculated based on methods developed by the U.S. Census Bureau (Myrianthopoulos and French, 1968). Study parents were compared to national data and assigned a percentile rank for education and occupation of the head of household and household income. The composite measure represents an average of these percentiles; higher percentiles indicate higher relative socioeconomic standing (range:0-99). SES was dichotomized at the median percentile (43.0), creating a binary indicator of high vs. low socioeconomic standing. Lifetime parental mental illness was assessed during maternal interviews at study enrollment and the child's 7 year evaluation. A positive history was coded if, at either time point, the mother reported that she or the child's father had ever received psychiatric hospitalization or outpatient treatment for a mental health issue or substance abuse.

Neurodevelopmental variables. The range of factors considered here includes variables thought to negatively impact brain development or functioning (e.g., maternal smoking during pregnancy, PDCs) or represent early measures of cognitive dysfunction (e.g., IQ, aggressive/impulsive behavior).

Questions pertaining to maternal smoking during pregnancy were asked during the first prenatal visit and repeated at each subsequent visit until the time of delivery. From these repeated measurements, the maximum number of cigarettes smoked during pregnancy was

determined. These self-reported smoking behaviors were biochemically validated against serum cotinine concentrations derived from maternal sera (Klebanoff et al., 1998).

An overall indicator of pregnancy/delivery complications was created from prenatal and delivery records of the following problems (Buka et al., 1993): (1) chronic fetal hypoxia (eclampsia, maternal hypertension, hypotension, anemia, and/or diabetes); (2) prematurity (gestational age ≤ 36 weeks); and (3) other complications (placental problems, cord problems, labor > 20 hours, breech delivery, maternal shock, neonatal asphyxia, respiratory distress, and/or apnea). Since it has been suggested that particular types of PDCs may be more closely related to the development of ASB than others (Allen et al., 1998; Arseneault et al., 2002; Hodgins et al., 2001), each of the three general types of complications was also examined individually.

Infant birth weight was measured in grams at delivery. Children were classified as low birth weight or normal birth weight based on the World Health Organization cutoff of $< 2,500$ grams (Kramer, 1987). An indicator of being small-for-gestational age, defined as having a birthweight $\leq 10^{\text{th}}$ percentile for gestational age, was also created.

Behavioral observations were made by the examining psychologist during the age 7 psychological assessment (Nichols and Chen, 1981). Aggressive/impulsive behavior was assessed by psychologists' observations of child behavior during a two-hour battery of cognitive, sensory, and motor tests. Children were coded as aggressive/impulsive if they exhibited any of the following: (1) persistent resistance to demands or instructions; (2) frequent explosive or under-controlled behavior; (3) forcefulness or unnecessary roughness; and/or (4) unusual hostility.

An abbreviated version of the Wechsler Intelligence Scales for Children was also administered at age 7 by trained psychologists (Wechsler, 1963). This measure was used to

derive verbal, performance, and full scale IQ scores. The verbal IQ score was based on four subtests: information, comprehension, vocabulary, and digit span. Performance IQ, a measure of nonverbal ability, was based on the picture arrangement, block design, and coding subtests. Full scale IQ provided a general measure of both verbal and nonverbal abilities.

Adult antisocial behavior. Data on adult arrests were obtained from the state of Rhode Island via the Inmate Facility Tracking System at the Department of Corrections, Planning and Development unit. Arrest information was confirmed by matching the participant's name, date of birth, and, if available, social security number. The use of multiple identifying variables minimizes error due to the use of aliases and data entry problems (e.g., misspelling of names) (Geerken, 1994). Of the 505 participants with an identified arrest record, information regarding type of criminal offense(s) was available for most ($n=401$, 79.4%) and each offense was classified as either violent or nonviolent. In accord with previous studies (Brennan et al., 1999; Räsänen et al., 1999), the following were categorized as violent offenses: homicide, robbery, sexual offenses, and assault ($n=193$, 48.1% of those with information on type of offense; 7.0% of overall sample). All other offenses were coded as nonviolent (e.g., theft, breaking and entering, prostitution, and narcotics offenses) ($n=208$, 51.9% of those with information on type of offense; 7.5% of overall sample).

Self-reported adult ASB was collected during follow-up interviews for a subset of participants ($n=928$) using the antisocial personality disorder (ASPD) module of the Diagnostic Interview Schedule (Robins et al., 1997) for DSM-IV (American Psychiatric Association, 1994). Questions covered six of the seven adult criteria for ASPD: unlawfulness, deceitfulness, impulsivity, aggressiveness, recklessness, and irresponsibility. Individuals were classified as

having significant ASB if they met at least three of the six assessed criteria. This threshold was selected because three or more adult behaviors are needed for a DSM-IV diagnosis of ASPD.

Statistical Methods

We examined the relationship between each background and neurodevelopmental variable and adult ASB using bivariate logistic regression (Fitzmaurice et al., 1996; Fitzmaurice et al., 1995); the term *bivariate* as used here refers to the joint analysis of two outcomes. This methodology allowed us to fit a single multivariate logistic regression model for both official arrests and self-reported ASB simultaneously and assess whether exposure-outcome relationships differed depending on how ASB was ascertained. Bivariate logistic regression treats information collected on the outcome from various data sources as repeated measures and was implemented using a modified generalized estimating equations analysis (GEE) (Liang and Zeger, 1986; Zeger and Liang, 1986). Since subjects needed information on adult ASB from only one source (official records or self-reports) to contribute to the analysis, data on all 2,776 participants with complete covariate information were utilized.

In these modified GEE models we included the predictors of interest and a binary variable designating whether adult ASB had been measured using official records or self-reports. We also included interactions between this binary indicator and the risk factors to allow the exposure-outcome relationship to differ across data sources. Differences in exposure-outcome relationships between official records and self-reports were evaluated by testing whether the coefficient for the interaction term was equal to zero. When significant interactions were found separate effect estimates for official records and self-reports are presented. Otherwise, the interaction term was removed and a single summary estimate was reported.

We accounted for both the within-person association between official records and self-reports and the sampling methods used in the adult follow-up studies. Ordinary GEE analysis models the association between pairs of responses using correlations. Yet because the outcomes studied here are binary, the alternating logistic regressions method was used to model the within-person association with log odds ratios, a more natural metric for binary data (Carey et al., 1993). Robust (or so-called “empirical”) standard errors were used in statistical testing for all models utilizing data from the adult follow-up studies.

Multinomial logistic regression models were used to examine whether the relationship between neurodevelopmental deficits and adult ASB differed by type of behavior (any violent, only nonviolent, no offenses). Only official arrest records were included in these models. All analyses controlled for participants’ age.

Results

Table 1 shows the distribution of covariates for the overall sample ($n=2,776$), and among two subgroups: (1) participants with information on adult ASB from official records only ($n=1,848$); and (2) participants with data from both official arrest records and self-reports of engagement in ASB ($n=928$). The overall prevalence of adult ASB was found to vary across the two sources of outcome information. Self-reported ASB was over 1.5 times more common than official records (28.8% vs. 18.2%). Among subjects with both sources of information, 62.3% of those with an arrest record were classified as having significant adult ASB according to self-reports. However, only 42.7% of the participants who reported engaging in significant adult ASB had an official arrest record. We also compared the distribution of covariates across the two

subgroups of participants with differing information available on adult behavior problems. Overall, these subgroups were quite similar across study variables.

{Insert Table 1}

As shown in Table 2, all background characteristics, with the exception of parental mental illness, were associated with an increased odds of adult ASB in the unadjusted (crude) models. Effect estimates depended on how ASB was measured for three variables: sex (interaction term: $\chi^2=4.58$, $df=1$, $p=0.03$), Black race (interaction term: $\chi^2=17.89$, $df=1$, $P<0.0001$), and low SES (interaction term: $\chi^2=5.43$, $df=1$, $p=0.02$). For sex and race, effect estimates for both official records and self-reported ASB were significant but the magnitude of the association was larger for official arrests. These differences were upheld in the adjusted models. For instance, while males experienced a fivefold increased odds of adult ASB when the outcome was measured using official records (adjusted odds ratio [AOR]=4.97; 95% confidence interval [CI]: 3.92-6.30) males had an approximate threefold increased odds when self-reports were considered (AOR=3.25, 95% CI: 2.38-4.46). Alternatively, although the strength of the association between low childhood SES and adult ASB varied across official and self-reported outcomes in crude models, these differences did not persist after controlling for other background variables. In adjusted models, low SES was associated with a 49% increased odds of adult ASB regardless of how the outcome was ascertained (AOR=1.49, 95% CI: 1.22-1.81). Parental mental illness was significantly related to serious adult ASB after controlling for other background characteristics (AOR=1.28, 95% CI: 1.02-1.73).

{Insert Table 2}

Because neurodevelopmental risks for ASB may be sex specific, we initially tested for potential interactions of sex with each of these factors and their associated informant-risk factor

interaction terms. No significant sex interactions were identified. These interaction terms were therefore removed and sex was included as a covariate in adjusted models.

Crude models for the neurodevelopmental variables showed that (1) maternal smoking during pregnancy, PDCs, age 7 aggressive/impulsive behavior, and lower childhood IQ increased the odds of adult ASB, and (2) these associations largely did not depend on whether adult ASB was defined based on arrest records or self-reported behaviors. Only the association between IQ and adult ASB was found to significantly depend on how the outcome was assessed, yet these differences did not persist after controlling for background characteristics.

In adjusted models, maternal smoking during pregnancy was found to increase the odds of adult ASB by 42% (AOR=1.42, 95% CI: 1.18-1.73), and those with childhood aggressive/impulsive behavior had 1.38 times the odds of experiencing significant behavioral dysfunction years later (95% CI: 1.01-1.91), regardless of how the data on adult ASB were collected. Full scale childhood IQ and the verbal and performance subscales were all significantly related to adult ASB. For instance, a one standard deviation (15 point) increase in full scale IQ resulted in a 23% reduction in the odds of adult ASB (AOR=0.77, 95% CI: 0.69-0.86). However, the overall indicator of PDCs (AOR=1.09, 95% CI: 0.91-1.31), as well as each type of complication, were no longer significantly related to the outcome, suggesting original associations were confounded by background characteristics.

As shown in Table 3, there was no support for the hypothesis that neurodevelopmental deficits were more closely related to violent than to nonviolent criminal behavior.

{Insert Table 3}

Discussion

Our findings support a robust association between demographic and contextual characteristics (male sex, Black race, low SES, parental mental illness) and neurodevelopmental insults (maternal smoking during pregnancy, childhood behavior problems, lower IQ) and later ASB in adulthood. Relationships largely did not depend on whether ASB was assessed using official arrest records or self-reported behavior; only two significant differences were found in adjusted analyses. Males and Black participants were more likely to engage in adult ASB than their female and White counterparts, but associations were significantly stronger when based on official records versus self-reports.

Some existing studies indicate that the extent of agreement between official records and self-reports may vary by race and sex (Jolliffe et al., 2003; Kirk, 2006; Maxfield et al., 2000; Piquero and Brame, 2008). For instance, failure to self-report behavior recorded in official records has sometimes been found to be more common among Blacks than Whites, possibly leading studies relying solely on self-report data to underestimate associations between race and adult criminal outcomes (Maxfield et al., 2000). Our findings are also consistent with an alternative explanation, i.e., Black individuals are disproportionately arrested for their criminal offenses. Future research is needed to clarify the reasons underlying such findings. The association between race and ASB is complex and investigators should also seek to identify moderating or mediating variables that may partly explain why Black individuals may be at increased risk for ASB.

Maternal smoking during pregnancy, childhood aggressive/impulsive behavior, and IQ were all independently associated with adult ASB after controlling for background characteristics. These findings are largely consistent with the published literature but extend prior results in important ways. While most previous research has focused exclusively on males,

our results suggest that the associations between indicators of neurodevelopmental functioning and later ASB apply to females as well. Our results further suggest that spatial or nonverbal cognitive deficits, in addition to verbal impairments, may also be related to later ASB. While deficits in verbal IQ have been shown to be a robust risk factor for ASB into adulthood (Sampson and Laub, 1993), less is known about whether deficits in spatial functions or nonverbal abilities also characterize those with later ASB (Raine et al., 2005). We found no evidence that these factors are more closely associated with violent than nonviolent behavior.

We did not, however, find a significant effect for PDCs and low birth weight in adjusted analyses. Previous studies have typically found no evidence or only weak evidence of an independent association between PDCs and adult ASB and criminal offending (Hodgins et al., 2001). The role of low birth weight is also uncertain, showing closer associations with attention deficit hyperactivity disorder (Hack et al., 2004; Nigg and Breslau, 2007; Wiles et al., 2005). It is also possible that these early neurodevelopmental deficits may only exert an influence on the risk of ASB when coupled with additional environmental risks (e.g. young maternal age, lower socioeconomic status) (Raine, 2002; Vaske et al., 2015). Findings from the current study, however, are important in showing that the lack of any direct effect is not due to the use of official vs. self-reported antisocial outcomes or the failure to distinguish between violent and nonviolent behaviors.

This study has several potential limitations. First, arrest record searches were limited to Rhode Island. Although on-going tracking efforts suggest that the majority of the cohort has remained in Rhode Island, we likely underestimated the true occurrence of arrests. A higher percentage of Black (as compared to White) participants have continuously remained in Rhode Island, but this difference was small. Consequently, it is unlikely that differential migration

effects across racial groups had a meaningful impact on observed associations. Second, our study was not designed to identify causal associations. Although we controlled for the effects of important background and contextual characteristics, we did not adjust for other potentially important variables (e.g., parental antisocial behavior, poor parenting practices). It is likely that we incompletely measured other variables, such as parental mental illness. Our operationalization may have led to an underestimation of the true extent of parental psychopathology, particularly among participants from underserved communities, and affected observed associations. Relatedly, although childhood aggressive/impulsive behavior was assessed using standardized procedures, it is possible that the accuracy of this measure differed across racial or economic groups. Third, our analyses focused on a group with heterogeneous types of ASB. Although the strength of associations between neurodevelopmental risks and adult ASB did not differ for violent versus nonviolent criminal behavior, it is possible that some of these relationships may be more pronounced among other forms of ASB.

The current study also has several notable strengths, including the use of prospectively collected information on neurodevelopmental risks, the inclusion of both males and females, the long length of follow-up, and information on both violent and nonviolent criminal behavior. But perhaps the greatest strength of our study was our use of a flexible analytic method that allowed us to incorporate multiple sources of information on ASB in a meaningful way. We were able to both examine whether the relationship between each particular neurodevelopmental characteristic and ASB differed depending on the method used to ascertain ASB, and in the absence of any significant differences, combine information obtained from official records and self-reports. The limitations of arrest records and self-reports of engagement in ASB are well

documented. Combining information from these different data sources likely increased the reliability of our measure of ASB.

Conclusions

Understanding the relationship between early neurodevelopment deficits and the risk of later serious ASB has important implications for theory, research, and practice. Our findings suggest a cluster of demographic/contextual factors and early neurodevelopment deficits that increase the risk of engaging in antisocial and criminal behavior in adulthood. Developmental theories of life-course-persistent antisocial behavior propose that an interplay between trait vulnerability and environmental factors produces antisocial continuity (Moffitt, 1993). These data are consistent with this literature, suggesting that adult ASB has roots in both early environmental deprivation (e.g., low socioeconomic status) and neurodevelopmental insults. Children who exhibit those early neurodevelopmental problems identified in the current study might benefit from early intervention to forestall the later development of serious behavioral difficulties.

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Fig 1. Attrition and follow-up of Providence Collaborative Perinatal Project (CPP) participants

ASB=antisocial behavior. Of the excluded participants ($n=362$), the majority were omitted due to missing data on one or more covariates, mostly childhood socioeconomic status. Due to the small number of non-Black minorities these participants were also excluded. All included participants ($n=2,776$) had outcome information on adult ASB from at least one data source: $n=1,848$ were included in the adult arrest records search only; $n=928$ also self-reported on their engagement in ASB during adult interviews.

Table 1 Characteristics of Total Sample and Subgroups with Differing Sources of Data on Adult Antisocial

Behavior				
		Subgroup 1: Arrest	Subgroup 2: Arrest	Comparison of
	Total Sample	Record Data Only	Record Data and	Subgroups
Characteristics	(<i>n</i> =2,776), %	(<i>n</i> =1,848), %	Self-Reported	1 and 2
			Behavior	<i>P</i> -value ^a
			(<i>n</i> =928), %	
Background / Contextual				
Male	49.3	48.2	51.4	0.13
Black race	22.4	22.8	21.8	0.52
Low socioeconomic status	48.2	48.2	48.1	0.98
Parental mental illness	15.4	15.1	16.2	0.46
Neurodevelopmental				
Any maternal smoking during pregnancy	61.8	62.6	60.2	0.24
Any pregnancy/delivery complication	43.3	43.0	44.0	0.59
Low birth weight	8.9	9.0	8.7	0.84
Small for gestational age	10.9	11.0	10.8	0.88
Any age 7 aggressive/impulsive behavior	6.8	6.8	6.8	0.94
Age 7 full scale IQ, mean (SD)	95.8 (13.6)	94.4 (13.8)	98.5 (12.7)	<0.0001
Adult Antisocial Behavior				
Any arrest record	18.2	17.4	19.7	0.14
Any violent offense	7.2	6.8	8.1	0.15
Self-reported behavior ^b	---	---	28.8	---

^a*P*-values from χ^2 statistics obtained from logistic regression models. Analyses control for participants' age.

^bDefined as meeting at least three of the six assessed DSM-IV criteria for antisocial personality disorder.

Table 2 Risk of Adult Antisocial Behavior (ASB) in Relation to Background and Neurodevelopmental

Characteristics (<i>n</i> =2,776)				
Characteristics	Bivariate Logistic Regression ^a			
	Crude Models ^b		Adjusted Models ^c	
	Any Arrest	Self-Reported	Any Arrest	Self-Reported
	Record	Adult ASB	Record	Adult ASB
	OR (95% CI)	OR (95% CI)	AOR (95% CI)	AOR (95% CI)
Background / Contextual				
Male	4.62 (3.65-5.83)	3.15 (2.31-4.29)	4.97 (3.92-6.30)	3.25 (2.38-4.46)
Black race	3.15 (2.52-3.92)	1.53 (1.10-2.12)	3.39 (2.67-4.30)	1.62 (1.14-2.29)
Low socioeconomic status	1.74 (1.42-2.13)	1.21 (0.90-1.61)	1.49 (1.22-1.81)	
Parental mental illness	1.18 (0.91-1.52)		1.28 (1.02-1.73)	
Neurodevelopmental				
Any maternal smoking during pregnancy	1.42 (1.18-1.71)		1.42 (1.18-1.73)	
Any pregnancy/delivery complication	1.25 (1.05-1.48)		1.09 (0.91-1.31)	
Chronic fetal hypoxia	1.23 (1.01-1.52)		1.06 (0.86-1.32)	
Premature birth	1.23 (0.89-1.70)		1.06 (0.76-1.47)	
Any other complications	1.14 (0.94-1.39)		1.09 (0.89-1.34)	
Low birth weight	0.79 (0.56-1.11)		0.84 (0.60-1.16)	
Small for gestational age	0.89 (0.68-1.17)		1.02 (0.77-1.35)	
Any age 7 aggressive/impulsive behavior	1.68 (1.23-2.29)		1.38 (1.01-1.91)	
Age 7 full scale IQ ^d	0.65 (0.58-0.72)	0.86 (0.73-1.02)	0.77 (0.69-0.86)	
Verbal IQ ^d	0.67 (0.60-0.75)	0.74 (0.67-0.82)	0.79 (0.71-0.88)	
Performance IQ ^d	0.71 (0.64-0.79)	0.74 (0.68-0.82)	0.83 (0.73-0.91)	

OR=odds ratio; CI=confidence interval; AOR=adjusted odds ratio.

^aSingle estimates indicate common effects for official arrest records and self-reported ASB; separate estimates are shown for effects that are significantly different ($p<0.05$) across official records and self-reports.

^bORs represent the association between each characteristic and the outcome, adjusted for participants' age.

^cAORs represent the association between each characteristic and the outcome, adjusted for participants' age and all (other) background variables.

^dORs/AORs are expressed for a one standard deviation change (15 points) in IQ scores.

Table 3 Risk of Violent and Nonviolent Criminal Behavior in Relation to Neurodevelopmental Characteristics

Neurodevelopmental Characteristics	Adjusted Multinomial Logistic Regression Models ^a	
	Any Violent Offense	Only Nonviolent
	vs. No Offense	Offense(s) vs. No
	(<i>n</i> =2,464)	Offense (<i>n</i> =2,479)
	AOR (95% CI)	AOR (95% CI)
Any maternal smoking during pregnancy	1.27 (0.91-1.77)	1.42 (1.04-1.95)
Any pregnancy/delivery complication	1.10 (0.80-1.50)	1.38 (1.03-1.84)
Low birth weight	0.78 (0.43-1.42)	0.85 (0.50-1.44)
Small for gestational age	0.87 (0.50-1.52)	1.07 (0.67-1.69)
Any age 7 aggressive/impulsive behavior	1.19 (0.69-2.05)	1.46 (0.90-2.39)
Age 7 full scale IQ ^b	0.64 (0.54-0.78)	0.72 (0.60-0.85)
Verbal IQ ^b	0.64 (0.52-0.77)	0.74 (0.62-0.88)
Performance IQ ^b	0.76 (0.65-0.90)	0.77 (0.66-0.90)

AOR=adjusted odds ratio; CI=confidence interval.

^aAnalyses utilize data from official arrest records only. AORs represent the association between each predictor and the 3-level outcome variable (any violent offence, only nonviolent offense(s), no offense), adjusted for participants' age, sex, race, socioeconomic status, and parental mental illness.

^bAORs are expressed for a one standard deviation change (15 points) in IQ scores.