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Psychopathic traits in adolescents are associated with higher structural connectivity

Louise E. Pape [a,*], Moran D. Cohn [a], Matthan W.A. Caan [b], Guido van Wingen [c], Wim van den Brink [c], Dick J. Veltman [d], Arne Popma [a,e]

[a] Department of Child and Adolescent Psychiatry, VU University Medical Center Amsterdam, Duivendrecht, The Netherlands
[b] Department of Radiology, Academic Medical Center University of Amsterdam, Amsterdam, The Netherlands
[c] Department of Psychiatry – Amsterdam Institute for Addiction Research, Academic Medical Center University of Amsterdam, Amsterdam, The Netherlands
[d] Department of Psychiatry, VU University Medical Center Amsterdam, Amsterdam, The Netherlands
[e] Institute of Criminal Law & Criminology, Faculty of Law, Leiden University, Leiden, The Netherlands

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ABSTRACT

Altered structural connectivity has been reported in antisocial juveniles, but findings have been inconsistent. Given the phenotypical heterogeneity among individuals showing antisocial behavior, specification of the association between structural connectivity and the dimensions of psychopathic traits (i.e., callous-unemotional, grandiose-manipulative, and impulsive–irresponsible traits) may aid in more reliably elucidating the neural mechanisms underlying antisocial behavior during adolescence. In this study, a sample of 145 adolescents (mean age 17.6, SD 1.6) from a childhood arrestee cohort participated in a neuroimaging protocol including diffusion tensor imaging (DTI). Fractional anisotropy (FA), radial diffusivity (RD) and axial diffusivity (AD), as obtained by tract-based spatial statistics, were associated with juveniles' scores on the Youth Psychopathic Traits Inventory. Grandiose-manipulative traits were positively associated with FA and negatively with RD in a wide range of white matter tracts, suggesting abnormal myelination related to these traits. Callous-unemotional traits were positively associated with FA and AD in specific white matter tracts, including the corpus callosum and corticospinal tract. The differential associations between dimensions of psychopathic traits and measures of structural connectivity support the notion that multiple distinct neural mechanisms underlie antisocial and psychopathic development.

1. Introduction

Psychopathic traits have been associated with the development of severe and persistent antisocial behavior (Frick et al., 2014). Like many other mental health problems (Insel et al., 2010), psychopathy is increasingly being conceptualized as a disorder of the brain (Kiehl, 2006). Neuroimaging studies in adult psychopaths have consistently shown abnormalities in the structure, function and connectivity in several brain regions, including the amygdala, orbitofrontal cortex, anterior and posterior cingulate cortex and other (para) limbic structures (Anderson and Kiehl, 2012). In adult samples, however, substance abuse and other features of an antisocial lifestyle may have exacerbated or confounded previous results (Blair, 2003). As such, investigating the neural correlates of psychopathy in juveniles is of added value to understand its etiology. Moreover, most studies on psychopathy have been conducted in a categorical fashion, while psychopathy may be more accurately viewed as a continuum (Edens et al., 2006) with separate dimensions related to distinct neurobiological correlates (Anderson and Kiehl, 2012). In general, dimensional investigations that cut across traditional diagnostic boundaries, as advocated by the Research Domain Criteria (RDoC) initiative (Insel et al., 2010), may be more adequate to fully grasp the pathophysiological processes underlying psychiatric disorders. Moreover, such analyses may increase power (Cohen, 1983), reliability (Button et al., 2013) and specificity (Insel et al., 2010).

Most initial psychopathy studies assumed a two-factor model of psychopathy, describing 'affective-interpersonal' and 'unstable and antisocial lifestyle' features (Harpur et al., 1989). While there is still substantial debate on the status of antisocial behavior being either an integral part of the psychopathy construct (Hare and Neumann, 2009) or rather a consequence of its other features (Cooke and Michie, 2001), recent studies have converged on a three-factor model of the psychopathic personality, consisting of callous-unemotional, grandiose-manipulative and impulsive–

* Correspondence to: NYU School of Medicine, Department of Radiology/Center for Biomedical Imaging, 660 First Avenue, 4th Floor, New York, NY 10016, USA. Fax: +1 212 263 7541.
E-mail address: louise.pape@nyumc.org (L.E. Pape).

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irresponsible traits (Cooke and Michie, 2001; Salekin et al., 2004). Indeed, there is increasing evidence for the assertion that specific psychopathy dimensions have distinct behavioral (Feilhauer and Cima, 2013) and neurobiological correlates (Marsh et al., 2008; Sebastian et al., 2012; Carré et al., 2013; Cohn et al., 2013).

Most of the recent neurobiological studies on the distinct correlates of psychopathic traits dimensions have investigated regional brain activation. Although these studies may provide evidence for regional cortical dysfunctions, complex mental health problems like psychopathy are increasingly being conceptualized as disorders of brain *circuits* (Insel et al., 2010). As network functionality is critically dependent on the white matter connections between cortical brain regions, analysis of its microstructure is likely to enhance our understanding of the neurodevelopmental origins of psychopathy. Diffusion tensor imaging (DTI) is a non-invasive technique that is increasingly used to examine subtle changes in the microstructural organization of white matter pathways (Jones, 2008). In DTI studies, structural connectivity is most commonly quantified as fractional anisotropy (FA), an index roughly representing the proportion of diffusion in the direction parallel to the axonal bundle (axial diffusivity, AD) relative to perpendicular diffusion (radial diffusivity, RD). Recent research has suggested that separate analysis of AD and RD may capture neurobiologically distinct aspects of microstructural abnormalities, with AD being more specific to axonal degeneration and RD being modulated by myelin in white matter (Beaulieu, 2002; Song et al., 2003).

So far, only a few studies have investigated the relation between specific dimensions of psychopathic traits and white matter microstructure. In adults, only one study in a small sample of psychopathic offenders ($n=11$) employed a dimensional approach based on the two-factor model of psychopathy, showing negative associations between the interpersonal-affective dimension and FA in an amygdala-prefrontal network, and between the irresponsible–antisocial dimension and FA in a striatal network (Hoppenbrouwers et al., 2013). In juveniles, two studies have assessed the association between psychopathic traits and structural connectivity. The first study showed a positive association between callous-unemotional traits and mean FA in the uncinate fasciculus (UF) in a sample including both healthy and conduct disordered (CD) juveniles ($n=43$) (Sarkar et al., 2013). The second study reported a positive association between impulsivity and FA in the corpus callosum in a sample of CD youths ($n=36$) (Zhang et al., 2014). While these small-scale studies suggest distinct effects of psychopathy dimensions, their inconsistent results and modest sample sizes mean that these findings need replication. Moreover, none of these studies has systematically investigated the association between variance uniquely related to one of the (related) psychopathic traits dimensions and structural connectivity.

In the current study, we acquired DTI data and assessed psychopathic traits in a large adolescent sample of childhood arrestees representing a broad spectrum of risk factors for antisocial development. The resulting sample ranged from typically developing to severely disordered, thereby providing a continuous distribution of psychopathic traits. Moreover, in addition to simple regression, we performed multiple regression analyses in order to assess the unique associations between the three dimensions of psychopathic traits and FA. To aid interpretation of any study findings, we repeated the same analyses on AD and RD measures. Based on the two studies in juvenile samples described above, we hypothesized that callous-unemotional traits would be positively correlated with structural connectivity in the UF and other tracts connecting temporal and frontal cortices (Sarkar et al., 2013), while impulsive–irresponsible traits might be positively associated with FA in the corpus callosum (Zhang et al., 2014).

2. Methods

2.1. Subjects and procedure

This study is embedded in a larger investigation prospectively following a cohort of 364 childhood arrestees, all of whom had been arrested by the police before the age of criminal responsibility in the Netherlands (12 years), for a range of acts that would be prosecutable above this age (e.g. petty theft, arson, vandalism, trespassing, burglary, assault, sexual abuse and robbery), excluding status offenses. Thus far, they have been assessed in four waves: mean age at study entrance 10.8 (SD 1.5) years and mean age at wave three 12.9 (SD 1.5) years (van Domburgh et al., 2009). Wave four included a neuroimaging protocol in which DTI data were acquired. Participants for this MRI study ($n=150$) were recruited from subgroups at low ($n=37$), medium ($n=57$) and high-risk ($n=56$) for antisocial development to represent the entire spectrum of psychopathic traits (see Supplementary material for recruitment strategy). From the 150 subjects participating in the neuroimaging protocol, three were excluded because of missing questionnaires and two subjects were excluded because of scanning artifacts. This yielded a final sample of 145 participants (mean age 17.6 SD 1.6). See Table 1 for a description of this sample in terms of demographic variables, psychometric measures and diagnoses. The study was approved by the VU University medical center Amsterdam Institutional Research Board. After recruitment, all participants (and their parents/custodians, if age of the participant was below 18) signed for informed consent and were visited at home for a structured psychiatric interview and questionnaires. On a separate occasion, participants completed the MRI protocol.

2.2. Clinical assessments

The Youth Psychopathic Traits Inventory (YPI) is a valid and reliable (Skeem and Cauffman, 2003) 50-item self-report instrument that was developed in order to study personality traits associated with adult psychopathy in juvenile community samples (Andershed et al., 2007). To ensure that all participants were able to understand the questions, the Dutch child version of the YPI was used (Baardewijk et al., 2008). This version has been shown to have good 6-month test–retest reliability (ICC range 0.61–0.76). Two age-specific school-related items in the impulsive–irresponsible scale of the child version were not appropriate for our age group and were therefore deleted, leaving a total of 48 items (range: 1–4). In the current study, internal consistency (Cronbach's α) of the total score and its constituting dimensions were excellent: callous-unemotional traits $\alpha=0.88$; grandiose-manipulative traits $\alpha=0.93$; impulsive–irresponsible traits $\alpha=0.88$; and YPI total score $\alpha=0.95$. The three psychopathy dimensions were significantly correlated (see Table S1 in the supplementary material). In addition, two subtests (vocabulary and block-design) of the Wechsler Intelligence Scale for Children-version III (WISC-III) (Wechsler, 1974) were used in previous waves to estimate intelligence in the current sample. See Supplementary material for complete assessment

Table 1
Descriptive statistics ($n=145$).

Demographics	*N* (%)/mean ± SD (range)
Male gender	125 (86.2%)
Low SES neighborhood	80 (55.9%)
Non-western ethnicity	38 (26.2%)
Age	17.6 ± 1.60 (12–20)
IQ	90.8 ± 12.8 (59–128)
Psychometric measures	Mean ± SD (range)
YPI callous-unemotional	24.6 ± 7.15 (15–55)
YPI grandiose-manipulative	30.2 ± 8.60 (20–61)
YPI impulsive–irresponsible	28.4 ± 7.62 (13–49)
YPI total psychopathic traits	83.2 ± 19.5 (50–157)
RPQ aggression	8.50 ± 4.61 (0–20)
CBCL internalizing	51.3 ± 10.7 (33–77)
YSR internalizing	47.7 ± 9.99 (30–75)
CBCL externalizing	52.1 ± 11.3 (34–78)
YSR externalizing	52.7 ± 10.0 (37–77)
DSM-IV diagnoses	*N* (%)
ADHD	46 (31.7)
DBD	37 (25.5)
PTSD	2 (1.4)

SES=Socio-economic status; RPQ=reactive proactive aggression questionnaire; YPI=youth psychopathic traits inventory; CBCL=child behavior checklist; YSR=youth self report; ADHD=attention deficit hyperactivity disorder; DBD=disruptive behavior disorders; PTSD=post-traumatic stress disorder.