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Emotional detachment in psychopathy: Involvement of dorsal default-mode connections

Arjun Sethi [a,b,*], *Sarah Gregory* [b], *Flavio Dell'Acqua* [a], *Eva Periche Thomas* [a], *Andy Simmons* [c], *Declan G.M. Murphy* [b], *Sheilagh Hodgins* [d], *Nigel J. Blackwood* [b,1] and *Michael C. Craig* [a,b,1]

[a] *NatBrainLab, London, UK*
[b] *Department of Forensic and Neurodevelopmental Sciences, Institute of Psychiatry, London, UK*
[c] *NIHR Biomedical Research Centre for Mental Health, Institute of Psychiatry, King's College London, London, UK*
[d] *Department de Psychiatrie, Universite de Montreal, Canada*

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ABSTRACT

Criminal psychopathy is defined by emotional detachment [Psychopathy Checklist – Revised (PCL-R) factor 1], and antisocial behaviour (PCL-R factor 2). Previous work has associated antisocial behaviour in psychopathy with abnormalities in a ventral temporo-amygdala-orbitofrontal network. However, little is known of the neural correlates of emotional detachment. Imaging studies have indicated that the ‘default-mode network’ (DMN), and in particular its dorsomedial (medial prefrontal – posterior cingulate) component, contributes to affective and social processing in healthy individuals. Furthermore, recent work suggests that this network may be implicated in psychopathy. However, no research has examined the relationship between psychopathy, emotional detachment, and the white matter underpinning the DMN. We therefore used diffusion tensor imaging (DTI) tractography in 13 offenders with psychopathy and 13 non-offenders to investigate the relationship between emotional detachment and the microstructure of white matter connections within the DMN. These included the dorsal cingulum (containing the medial prefrontal – posterior cingulate connections of the DMN), and the ventral cingulum (containing the posterior cingulate – medial temporal connections of the DMN). We found that fractional anisotropy (FA) was reduced in the left dorsal cingulum in the psychopathy group ($p = .024$). Moreover, within this group, emotional detachment was negatively correlated with FA in this tract portion bilaterally (left: $r = -.61$, $p = .026$; right: $r = -.62$, $p = .023$). These results suggest the importance of the dorsal DMN in the emotional detachment observed in individuals with psychopathy. We propose a ‘dual-network’ model of white matter abnormalities in the disorder, which incorporates these with previous findings.

* *Corresponding author*. NatBrainLab, Department of Forensic and Neurodevelopmental Sciences, Institute of Psychiatry, 16 De Crespigny Park, London, SE5 8AF, UK.
E-mail address: arjun.sethi@kcl.ac.uk (A. Sethi).
[1] Joint last authors.
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1. Introduction

Criminal psychopathy is characterised by antisocial behaviour and a constellation of affective and interpersonal traits including callousness, shallow affect, and manipulativeness (R. D. Hare, 1991). These behavioural characteristics have a significant negative impact on society. For instance, individuals with psychopathy constitute approximately 15–20% of the prison population, and commit a disproportionate number of violent and recidivistic offences (Hart & Hare, 1997; Hemphill, Hare, & Wong, 1998) that cost the USA over $460 billion a year (Kiehl & Hoffman, 2011). It has been proposed that psychopathy is a disorder of the 'paralimbic' system (Kiehl, 2006), including structures such as the amygdala and ventromedial prefrontal cortex (Blair, 2008).

Investigation into the neural basis of psychopathy has been facilitated by the development of *in vivo* brain imaging and reliable, well-validated, instruments that permit quantification of specific traits and behavioural tendencies. Factor analysis of these traits, using the Psychopathy Checklist – Revised (PCL-R), suggests that they can be divided into dimensions of '*emotional detachment*' (factor 1) and '*antisocial behaviour*' (factor 2) (Hare, 1991, 2003; Hare et al., 1990; Harpur, Hakstian, & Hare, 1988; Harpur, Hare, & Hakstian, 1989). Factor 2 antisocial scores have been reported to be negatively correlated with the microstructure of the right uncinate fasciculus (Craig et al., 2009), a ventral limbic tract connecting the anterior temporal cortex and amygdala with orbitofrontal regions (Catani & Thiebault De Schotten, 2012). The relationship between psychopathy/antisocial behaviour and the uncinate has since been confirmed (Motzkin, Newman, Kiehl, & Koenigs, 2011; Sundram et al., 2012). Moreover, the association between specific regions within this network and psychopathy and antisocial behaviour is supported by an increasing number of neuropsychological (Blair, Colledge, Murray, & Mitchell, 2001; Budhani & Blair, 2005; Budhani, Richell, & Blair, 2006; Levenston, Patrick, Bradley, & Lang, 2000), lesion (Barrash, Tranel, & Anderson, 2000; Blair & Cipolotti, 2000; Damasio, Grabowski, Frank, Galaburda, & Damasio, 1994; Harlow, 1993, 1999; Kluver & Bucy, 1997; Saver & Damasio, 1991), stimulation (King, 1961) and *in vivo* brain imaging studies (Boccardi et al., 2011; Kiehl et al., 2001; Raine, Buchsbaum, & LaCasse, 1997; Raine, Lencz, Bihrle, LaCasse, & Colletti, 2000; Veit et al., 2002).

These prior studies have been important first steps in understanding psychopathy. However, antisocial behaviour is not specific to psychopathic individuals (Harpur, et al., 1989; Skeem & Cooke, 2010), and it is emotional detachment (factor 1) that differentiates psychopathic personality from the broader diagnosis of Antisocial Personality Disorder. Moreover, emotional detachment in adults with psychopathy is presumed to reflect a heritable developmental trajectory from callous-unemotional traits in childhood (Barry et al., 2000; Forsman, Lichtenstein, Andershed, & Larsson, 2008; Frick, Kimonis, Dandreaux, & Farell, 2003; Frick & Viding, 2009; Viding, Blair, Moffitt, & Plomin, 2005; Wootton, Frick, Shelton, & Silverthorn, 1997). Investigating the neural correlates of factor 1 traits is therefore likely to be of central importance to understanding the neurodevelopment of psychopathic personality. Mounting evidence suggests that the 'default-mode' network (DMN) is linked to psychopathy, and may be related to emotional detachment in the disorder.

The DMN is a subdivision of the limbic system that has largely been associated with introspective and self-referent processing (Gusnard, Akbudak, Shulman, & Raichle, 2001; Johnson et al., 2006; Kelley et al., 2002). This network consists of a set of regions that are active and functionally intercorrelated under resting-state conditions (Raichle et al., 2001). These include the posterior cingulate cortex (PCC), the medial prefrontal cortex (mPFC), the medial temporal lobe (MTL), and the angular gyrus (Fox et al., 2005; Fransson, 2005; Raichle et al., 2001; Shulman et al., 1997). These regions are of specific interest due to their overlap with areas involved in affective processing (Kiehl et al., 2001; Maddock, Garrett, & Buonocore, 2003). This network has also been strongly implicated in social processing (Buckner, Andrews-Hanna, & Schacter, 2008; Vollm et al., 2006) and moral judgement (Greene, Sommerville, Nystrom, Darley, & Cohen, 2001; Harrison et al., 2008). The DMN is therefore well placed to play an important role in the profound emotional detachment in psychopathy.

The relevance of the DMN to psychopathy is further supported by recent functional MRI studies that have reported abnormal activation and connectivity within this network among men with psychopathy (Glenn, Raine, & Schug, 2009; Motzkin, et al., 2011; Pujol et al., 2011). Similarly, structural imaging studies of both adults with psychopathy (Boccardi et al., 2011; Ermer, Cope, Nyalakanti, Calhoun, & Kiehl, 2012; Gregory et al., 2012; de Oliveira-Souza et al., 2008; Yang, Raine, Colletti, Toga, & Narr, 2009) and boys with conduct disorder and callous-unemotional traits (De Brito et al., 2009; Rijsdijsk et al., 2010) have reported abnormal grey matter volume in DMN regions. Importantly, a preliminary study has reported that the degree of functional connectivity within a network containing DMN regions was related to emotional detachment in individuals with psychopathy (Juarez, Kiehl, & Calhoun, 2012). These studies collectively point towards the importance of the DMN in psychopathy, and perhaps emotional detachment in particular. However, it is unknown whether (i) previously observed functional differences in psychopathy are associated with abnormalities in the white matter anatomy of this network; (ii) whether any such differences in this network are related specifically to emotional detachment.

Direct white matter connections between the medial DMN regions (Greicius, Supekar, Menon, & Dougherty, 2009) lie within the cingulum, a long association tract which can be subdivided into functionally and anatomically distinct portions. For the purposes of this study, we identify two distinguishable portions: (i) the dorsal cingulum, connecting the PCC to the mPFC, which is related to social and emotional aspects of cognition; and (ii) the ventral cingulum, connecting PCC to the MTL, which is involved in memory and spatial orientation (Catani & Thiebault De Schotten, 2012).

In the current study we used DTI tractography to analyse the dorsal and ventral cingulum in offenders with psychopathy and age- and IQ-matched non-offenders. Based on prior work, we hypothesised that surrogate indices of