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Research report

The salience network and human personality: Integrity of white matter tracts within anterior and posterior salience network relates to the self-directedness character trait

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ABSTRACT

A prevailing topic in personality neuroscience is the question how personality traits are reflected in the brain. Functional and structural networks have been examined by functional and structural magnetic resonance imaging, however, the structural correlates of functionally defined networks have not been investigated in a personality context. By using the Temperament and Character Inventory (TCI) and Diffusion Tensor Imaging (DTI), the present study assesses in a sample of 116 healthy participants how personality traits proposed in the framework of the biopsychosocial theory of personality relate to white matter pathways delineated by functional network imaging. We show that the character trait self-directedness relates to the overall microstructural integrity of white matter tracts constituting the salience network as indicated by DTI-derived measures. Self-directedness has been proposed as the executive control component of personality and describes the tendency to stay focused on the attainment of long-term goals. The present finding corroborates the view of the salience network as an executive control network that serves maintenance of rules and task-sets to guide ongoing behavior.

1. Introduction

Human personality is thought to consist of a set of largely independent traits that – when considered together – can account for the bulk part of individual differences in affective, motivational, and social behavior. A trait taxonomy that has been shown to be particularly useful in neuroscientific and clinical research on personality roots in the biopsychosocial theory of personality (Cloninger, 1986; 1987; Cloninger et al., 1993). This theory combines ideas from learning theory, biopsychology, and social psychology to propose four temperament and three character traits. The temperament traits describe an individual's sensitivity to reward (“novelty seeking”), punishment (“harm avoidance”), social reinforcement (“reward dependence”), and his or her resistance to extinction (“persistence”). The character traits on the other hand describe an individual's self-concept as an autonomous being (“self-directedness”), a member of society (“cooperativeness”), and his or her relationship to spiritual ideas (“self-transcendence”). All seven traits are conceptualized as unipolar dimensions along which each individual can be classified. The Temperament and Character Inventory (TCI) has been put forward as a unified diagnostic tool for the assessment of the proposed seven personality traits (Cloninger, 1994).

A thriving issue for contemporary neuroscience is to describe individual differences in personality as a function of the nervous system and to identify the anatomical structures and their interplay that constitute personality traits in the human brain (Montag, 2016; Montag and Panksepp, 2017). Early trait theories have positioned that personality traits should be understood as psychophysical systems that mediate between stimuli and responses. This would be achieved by screening the vast array of

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incoming signals for trait-relevant content, and eliciting a typical and consistent emotional, motivational, and behavioral response (Allport, 1937). From a neurobiological perspective, this definition entails that traits should draw upon a multitude of subcortical and cortical processing modules that coordinate their efforts to link sensory perception, cognitive, affective and motivational processing, and memory representations for evoking an adaptive response. Individual differences are thought to arise from the sensitivity of these processing systems.

Traditionally, personality neuroscience studies have made use of functional task-activation assays to study brain-personality relationships. Such experiments seek to identify brain regions that respond to trait-relevant stimulation and then assess, whether the regions react differently in participants with varying trait levels. Over a range of different experimental set-ups and different personality assessment methods, this line of research has repeatedly confirmed that personality modulates how the brain responds to affective and cognitive stimulation (Canli et al., 2001; Cohen et al., 2005; Most et al., 2006; Reuter et al., 2004; Haas et al., 2007; Saggar et al., 2016).

Personality traits are conceptualized as relatively stable behavioral dispositions. Neural correlates of personality should therefore not only be reflected in the modulation of transient neural activity but should be visible in stable and stimulus-independent characteristics of the brain. This hypothesis has been extensively tested with structural imaging techniques. Evidence suggests that personality scores correlate with local gray and white matter concentrations oftentimes but not exclusively in brain areas whose response profile to stimulation is modulated by individual trait levels (Omura et al., 2005; Iidaka et al., 2006; Deyoung et al., 2010; van Schuerbeek et al., 2011; Liu et al., 2013; Riccelli et al., 2016). Functional and structural imaging studies have identified several brain regions with relevance for personality, however, no personality trait seems to be exclusively associated with one brain region (Calder et al., 2011; Kennis et al., 2013; Montag et al., 2013; Mincic, 2015). This evidence points towards the conceptual nervous system hypothesis that each personality trait is realized by a network comprising several brain regions. This puts imaging techniques in the focus that can assess connectivity between brain areas.

Recent years have seen the rise of a new set of brain imaging methods that use functional connectivity analyses to assess network scale interactions between different brain regions (Smith et al., 2013). Functional connectivity is operationalized via statistical dependencies in time series of neural activity (Friston, 1993). It is often assessed by means of functional magnetic resonance imaging (fMRI) in the resting-state, a stimulation-free state where research participants do not engage in any particular task (Fox and Raichle, 2007). A key observation from this line of research is that neural activity organizes itself into a set of resting-state networks (for review see van den Heuvel and Hulshoff Pol, 2010). Prominent examples for such resting-state networks are the default mode network (Greicius et al. 2003), the salience network (Seeley et al., 2007), and a frontal network with a presumed implication in executive control processes (Menon and Uddin, 2010). According to the three networks model, the three aforementioned networks constitute the brain's core networks with important implications for normal cognitive and affective functioning but also for a variety of disease states (Menon, 2011). Personality neuroscience has set out to explore relationships between individual differences in personality traits and functional connectivity within and between these networks, with the implicit goal of identifying the neural basis of the assumed psychophysical trait systems in the human brain (Markett et al., in press). Such studies have looked at relationships between personality traits and the functional connectivity profile of single brain regions (Adelstein et al., 2011; Aghajani et al.. 2013; Markett et al., 2013; Deris et al., 2017), single functional connectivity networks (Beaty et al., 2016; Markett et al., 2016), or brain-wide connectivity patterns (Gao et al., 2013; Servaas et al., 2015; Geerligs et al., 2015; Smith et al., 2015). For a detailed review of functional connectivity studies on individual differences see Vaidya and Gordon (2013).

Functional connectivity, however, is only one side of the coin. Structural connectivity in the form of white matter tracts builds the anatomical scaffold along which functional connectivity unfolds (Park and Friston, 2013). White matter can be examined by diffusion tensor imaging (DTI). DTI is an advanced MRI-technique in which the MRI-signal is sensitized to the tissue water diffusion rate. Unrestricted diffusion is termed isotropic, whereas directional diffusion called anisotropic. It is intuitive how diffusion will be anisotropic in coherent white matter bundles and, thus, reflects the orientational architecture of tissues. Microstructural features may be examined by DTI-derived scalars such as fractional anisotropy (FA).

Investigations of structural (DTI) and of functional connectivity, as revealed by resting-state fMRI, often yield coherent results (van den Heuvel et al., 2009; Honey et al., 2009; Horn et al., 2014). Both connectivity types, however, are not redundant and still provide unique information on their own (Buckner and Krienen, 2013). Figley et al. (2015) have recently published a set of probabilistic white matter atlases for the three core networks based on resting-state fMRI data. These atlases enable researchers to ascribe changes in white matter properties to resting-state networks and thus allow for a structural connectivity perspective on functional brain networks. Given the central role of these three networks and their assumed interactions for psychological functioning (Menon, 2011), the present work uses the probabilistic atlases for all three networks (the salience network, the default mode network, and the executive control network) to assess microstrutural features of within-network white matter tracts and to relate these estimates to individual differences in traits proposed by the biopsychosocial TCI framework of personality.

2. Results

Results from the regression analyses are given in Table 1. Controlling for age and gender, we observed larger network-wide white matter integrity in the salience network in participants scoring higher on the self-directedness character trait. No other personality traits were entered into the regression models by the stepwise procedure. The correlation between self-directedness and structural integrity of the salience network is shown in Fig. 1. No personality associations were observed for the default mode and executive control networks.

In a next step, we examined whether similar relationships with self-directedness could be observed for the anterior salience network (aSN) and the posterior salience network (pSN) separately. Partial correlation coefficients are given in Table 2. The correlation was similar for the anterior and posterior part of the salience network, indicating a positive relationship between self-directedness and the salience network as a whole.

The associations between the sub-scales of self-directedness and network-wide white matter integrity were explored using partial correlations (corrected for age and gender, see methods). All correlations for the salience network as a whole as well as its anterior and posterior part and the five sub-scales of self-directedness are given in Table 2. The most robust relationship was observed for the SD3 (resourcefulness vs. inertia) and the SD4 (self-acceptance vs. self-striving) subscale.

For anatomical reference, the anterior and posterior salience networks are depicted in Fig. 2.