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GRAY AND WHITE MATTER CORRELATES OF THE BIG FIVE PERSONALITY TRAITS

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Abstract—Personality neuroscience defines the scientific study of the neurobiological basis of personality. This field assumes that individual differences in personality traits are related with structural and functional variations of the human brain. Gray and white matters are structural properties considered separately in previous research. Available findings in this regard are largely disparate. Here we analyze the relationships between gray matter (cortical thickness (CT), cortical surface area (CSA), and cortical volume) and integrity scores obtained after several white matter tracts connecting different brain regions, with individual differences in the personality traits comprised by the Five-Factor Model (extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience). These psychological and biological data were obtained from young healthy women. The main findings showed statistically significant associations between occipital CSA variations and extraversion, as well as between parietal CT variations and neuroticism. Regarding white matter integrity, openness showed positive correlations with tracts connecting posterior and anterior brain regions. Therefore, variations in discrete gray matter clusters were associated with temperamental traits (extraversion and neuroticism), whereas long-distance structural connections were related with the dimension of personality that has been associated with high-level cognitive processes (openness).

Key words: five-factor personality model, gray matter, white matter integrity, diffusion tensor imaging, tractography.

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Abbreviations: AF, arcuate fasciculus; CB, cingulum bundle; CC, corpus callosum; CGMV, cortical gray matter volume; CSA, cortical surface area; CT, cortical thickness; DTI, diffusion tensor images; FFM, Five-Factor Model; IFO, inferior frontal-occipital fasciculus; ILF, inferior longitudinal fasciculus; MRIs, magnetic resonance images; PCA, principal component analysis; UF, uncinate fasciculus.

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INTRODUCTION

Background

Personality neuroscience is aimed at testing the neurobiological basis of personality. This research is thought to contribute to our understanding of biological systems presumably supporting widespread personality differences (DeYoung and Gray, 2009; DeYoung et al., 2010). In this regard, the Five-Factor Model (FFM), or Big Five, is widely recognized. Personality traits summarize individuals' propensity to behave in a consistent and stable manner (McCrae and Costa, 2008), and, therefore, it is reasonable to assume that key features of brain structure and function support them. Individual differences in psychological factors may result, at least in part, from structural and functional large variations of the human brain (Colom and Thompson, 2011; Mueller et al., 2013).

The FFM includes these psychological traits: extraversion (E), agreeableness (A), conscientiousness (C), neuroticism (N), and openness to experience (O) (McCrae and Costa, 2008). E reflects the intensity of relationships with others, activity level, need for external stimuli, and enjoyment. A is defined by the tendency to trust others, honesty, altruism, conciliatory attitude, modesty, and social sensitivity. C evaluates the degree of organization, persistence, control, and motivation in behavior toward social goals. N assesses emotional adjustment, anxiety, hostility, depression, social anxiety, impulsivity, and vulnerability. Finally, O expresses receptivity to new experiences, and comprises facets such as fantasy, esthetics, responsiveness to feelings, tendency to change activities, intellectual interest, and criticism of established values. Therefore, the FFM can be seen as a comprehensive framework for studying human personality (John et al., 2008).

Here we analyze the relationship between brain structural differences and individual differences in these traits, relying on a neuroimaging approach. Gray matter and white matter are basic structural features of the human brain. Gray matter is thought to support information-processing capacity and variations in the amount of this index reflect number and density of neuronal bodies and dendritic arborization. White matter supports efficient flow of information in the brain and variations on its integrity reflect number and thickness of axons and their myelination (Zatorre et al., 2012).

There is a relatively small set of reports addressing the relationship between gray matter variations and individual differences in the Big Five (Omura et al., 2005; Wright et al., 2006, 2007; Blankstein et al., 2009; DeYoung et al., 2010; Cremers et al., 2011; Bjørnebekk et al., 2013; Kapogiannis et al., 2013). The heterogeneity of findings was underscored by the revision published by Hu et al. (2011) who analyzed volumetric studies based on voxel-based morphometry and published between 2002 and 2010. They suggested that the divergent treatment of well-known nuisance covariates (general biological measures, sex, or age) might help to account for the disparate findings. Regarding white matter, there is also a small set of studies relating this structural property with the FFM (McIntosh et al., 2013; Gurrera et al., 2007; Madsen et al., 2012; Xu and Potenza, 2012; Bjørnebekk et al., 2013; Liu et al., 2013; Booth et al., 2014). Reported findings are also largely heterogeneous.

The present study

Here we will analyze individual differences in gray matter indices obtained after applying Surface-Based Morphometry. Cortical gray matter volume (CGMV), cortical surface area (CSA), and cortical thickness (CT) values, obtained at the vertex level, will be related with the five personality traits, as assessed by the NEO Five-Factor Inventory (NEO-FFI, Costa and McCrae, 1992). Our main predictions are based on findings observed in previous studies: E will show positive correlations with CT in prefrontal areas (Bjørnebekk et al., 2013) and with CGMV in orbitofrontal cortex (DeYoung et al., 2010), A will be associated with superior temporal sulcus, temporo-parietal junction and posterior cingulate CGMV (DeYoung et al., 2010), C will be related with medial prefrontal CGMV (DeYoung et al., 2010), N will show negative correlations with CT and CGMV (Bjørnebekk et al., 2013) and with cingulate and medial prefrontal CGMV (DeYoung et al., 2010), and, finally, O will be associated with dorsolateral and anterior prefrontal CGMV (DeYoung et al., 2010).

Regarding white matter, we selected tracts connecting anterior with posterior regions, both hemispheres, and frontal-temporal regions (Schmahmann et al., 2008; Montag et al., 2012) (Fig. 1). Fractional anisotropy scores were computed for twelve white matter tracts (six per hemisphere) and these white matter integrity scores were correlated with the five personality traits. Five were association fiber tracts: arcuate fasciculus (AF), cingulum bundle (CB), inferior frontal-occipital fasciculus (IFO), inferior longitudinal fasciculus (ILF), and uncinate fasciculus (UF). The corpus callosum (CC) (anterior and posterior) was also analyzed. Therefore, a total of 12 tracts (for the left and right hemispheres) were drawn using a confirmatory technique based on Wakana et al.'s (2007) protocol. These tracts can be grouped according to the brain areas they connect: (1) posterior–anterior (ILF and IFO), (2) interhemispheric (CC and CB), and (3) frontal-temporal (UF and AF). ILF provides connections within ventral temporal and occipital cortex and toward the parietal lobule and the superior temporal sulcus. IFO connects parietal-occipital areas with dorsolateral premotor and prefrontal regions. The anterior part of the CC (or forceps minor) projects from the genu of the CC to prefrontal cortex, anterior cingulate cortex and supplementary motor cortex bilaterally. The posterior part of the CC (or forceps major) is the bundle of fibers projecting from the splenium of the CC and connects bilateral homotopic superior temporal areas and parietal-occipital areas. The CB links prefrontal areas with the precuneus and the posterior cingulate cortex. The UF links the temporal pole and parahippocampal gyrus with medial and orbital prefrontal cortex and also projecting to the amygdala. Finally, the AF connects dorsolateral prefrontal regions with the superior temporal gyrus (Wakana et al., 2007; Schmahmann et al., 2008; Haász et al., 2013).

Our hypotheses followed Xu and Potenza's (2012) guidelines: (a) E and A will show positive correlations with the integrity of tracts connecting prefrontal and parietal cortices (CB and IFO), (b) C will show positive correlations with tracts connecting prefrontal and parietal cortices, the amygdala, and the hippocampus (CB and UF), (c) N will show negative correlations with tracts connecting the prefrontal cortex with the amygdala (CB and UF), and (d) O will show positive correlations with tracts connecting both hemispheres (CC), and with those connecting the prefrontal, parietal, and temporal cortices, along with the basal ganglia (AF, CB, and IFO).

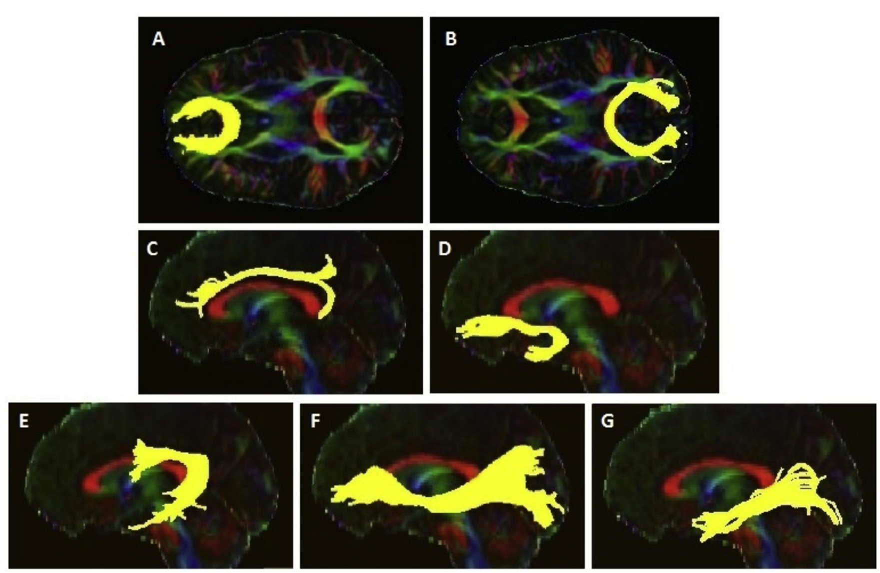

Fig. 1. DTI color map showing the white matter tracts analyzed in the present study. Top row: axial view of anterior corpus callosum or forceps minor (A) and posterior corpus callosum or forceps major (B). Middle row: sagittal view of cingulum bundle (C), and uncinate fasciculus (D). Bottom row: arcuate fasciculus (E), inferior frontal-occipital fasciculus (F), and inferior longitudinal fasciculus (G).