Cortical morphometry of the five-factor model of personality: Findings from the Human

Connectome Project full sample

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Abstract

This study is a conceptual replication of an existing large study ($N = 507$) on the surface-based morphometric correlates of Five-Factor Model (FFM) personality traits. Using another large sample drawn from the same population ($N = 597$), results were aggregated from both samples ($N = 1104$), providing the largest investigation into the neuroanatomical correlates of FFM personality traits to date. Multiple clusters of significant brain by personality associations were found in the aggregate sample, including one for Openness with cortical thickness in the left and right dorsolateral prefrontal cortex (DLPFC), one for Agreeableness with thickness in the left DLPFC, and one for Agreeableness with area and volume in the right DLPFC. Clusters were also found for Neuroticism with cortical surface area in the right DLPFC, for Neuroticism with cortical thickness in the DLPFC and medial prefrontal cortex, and for Neuroticism with area and volume in the cuneus. While many regions found in the prior study were confirmed in the new and full samples, others were not, highlighting the challenges in replicating even high-quality, well-powered studies. As a whole, the current results provide the strongest evidence to date on the neuroanatomical correlates of personality.

Keywords: Personality, MRI, Five Factor Model, Morphometry, Traits

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The Five Factor Model (FFM)¹ of personality has been a guiding framework for understanding how personality traits are related to a range of important biological, psychological, and social phenomena (McCrae and Costa, 1997). Traits include 1) Neuroticism, which is associated with negative emotional reactivity, 2) Extraversion, which is associated with a drive for affiliation and dominance, 3) Openness, which is associated with fantasy, interest in novelty, and liberalism, 4) Agreeableness, which is associated with nurturance, kindness, and social harmony, and 5) Conscientiousness, which is associated with orderliness and impulse control (John and Srivastava, 1999).

Due in part to technological advancements, as well as the promulgation of major research initiatives that encourage investigations into the biological foundations of psychological phenomena (e.g., Research Domain Criteria; (Insel *et al.*, 2010; Cuthbert and Insel, 2013), research on the neural bases of personality has burgeoned in the last decade (e.g., Allen & DeYoung, 2015), which is particularly relevant given personality's links to psychopathology (Kotov *et al.*, 2017) and a wide array of important outcomes (Ozer & Benet-Martinez, 2006). Historically, there are structural models of personality that are explicitly posited to capture specific physiological processes (e.g., Cloninger's Temperament and Character model, (Cloninger *et al.*, 1993); Eysenck's PEN model, (Eysenck and Eysenck, 1970), but the FFM has its roots in the lexical hypothesis, which proposes that the most socially-relevant information will be encoded most robustly in language (see John & Srivastava, 1999 for a review). Although the FFM was not initially constructed to capture specific physiological processes, it is amenable to

¹ Due to the high degree of empirical overlap between the FFM and the Big Five, we use FFM to refer to these shared traits.

predictions about which regions of the brain are relevant to particular traits (e.g., DeYoung et al., 2010). For example, Extraversion is partially comprised of the facet Dominance, and thus it could be hypothesized that it is associated with regions of the brain related to approach orientation (e.g., nucleus accumbens, medial prefrontal cortex, cingulate gyrus, amygdala; (Machado and Cantilino, 2016). Although several studies report structural MRI results indicating associations of gray matter volume in these regions with Extraversion, the direction of findings have been inconsistent across studies (Omura *et al.*, 2005; Cremers *et al.*, 2017).

In the literature review for their recent study, Riccelli *et al.*, (2017) suggest that findings across all FFM traits are inconsistent to date (e.g., Coutinho, Sampaio, Ferreira, Soares, & Gonçalves, 2013; DeYoung et al., 2010). There are several methodological considerations that may contribute to this heterogeneity, including low statistical power related to small sample sizes (Button *et al.*, 2013) and wide variation in age range across studies (e.g., Fjell & Walhovd, 2010). Furthermore, most of the extant work on the FFM and neuroanatomy has used voxel-based morphometry (VBM) to analyze the gray matter variance associated with FFM traits. Because of VBM's reliance on the measured intensity of voxels to assign a probability that each voxel represents gray or white matter, its index of gray matter volume can be difficult to interpret. VBM is also unable to assess specific features of cortical gray matter, such as cortical thickness and cortical surface area (Hutton *et al.*, 2009).

Noting these limitations, Riccelli and colleagues (Riccelli *et al.*, 2017) employed a surface-based morphometry (SBM; i.e., quantification of cortical morphometry) approach to investigate the neuroanatomical correlates of FFM traits using a large sample comprising approximately half (N=507) of the participants in the Human Connectome Project (HCP). Results suggest each trait was characterized by unique relations to SBM metrics. In brief,

Neuroticism was associated with a thicker cortical ribbon and a smaller surface area in prefrontal and temporal regions. Extraversion was linked to a thicker cortical ribbon in the precuneus, reduced gray matter volume in the superior temporal gyrus and entorhinal cortex, and greater cortical gyrification in the fusiform gyrus. Openness was correlated with thinner cortices, but greater area throughout the parietal, temporal, and frontal lobes. Agreeableness was associated with lower cortical thickness, area, and volume in the frontal and temporal regions. Finally, Conscientiousness was correlated with thicker prefrontal cortex and smaller surface area and gyrification in the middle/inferior temporal and lateral occipital gyrus. These authors concluded that there are numerous areas and metrics of the brain associated with personality traits, with the prefrontal cortex seeming to be the most important.

The Current Study

Since the publication of this article by Riccelli and colleagues (2017), the size of the available HCP dataset has more than doubled. In the current study, we first aimed to independently conceptually replicate the findings of Riccelli and colleagues (2017) using the 597 participants from the HCP dataset that were not included in their analyses. Second, we aimed to aggregate the results of the two studies across the full sample of 1104. In addition to a substantially increased sample size, our approach differed from that of Riccelli and colleagues (2017) in an important analytic respect. When examining the relations between an FFM trait and SBM indices, we did *not* control for the other four FFM traits. This decision was made due to documented construct validity concerns about meaningfully interpreting partialled personality variables, in that relations can be attenuated, or new and/or stronger relations can be discovered due to statistical suppressor effects (i.e., "perils of partialing"; Lynam, Hoyle, & Newman, 2006; Sleep, Lynam, Hyatt, & Miller, 2017). The interpretative issues related to partialled variables are

most pronounced if partialled personality variable X is significantly related to personality variable Y which has been controlled for. Although FFM traits are uniquely related to outcome indices (Roberts *et al.*, 2007), they are not orthogonal, and a meta-analysis suggests that FFM traits are inter-related as highly as Pearson's $r = -.32$ (Neuroticism-Conscientiousness; van der Linden, te Nijenhuis, & Bakker, 2010). As a result, we also reanalyzed the original sample of 507 without using other FFM traits as covariates. Thus, while the discrepant analytic methods mean that the primary analysis of this study is not a direct replication of Riccelli and colleagues (2017), we do also report the analysis using the other FFM traits as covariates in the full sample in Supplemental Materials. The current study provides the most well-powered investigation into the neuroanatomical correlates of FFM traits to date.

Methods

Participants

Structural MRI and self-reported personality data were collected from 1104 participants at Washington University as part of HCP between August 2012 and October 2015 and released in full on March 1, 2017. Demographic information about the full sample can be found in Table 1, alongside information about participants in the replication sample ($N = 597$) that were not included in the original sample ($N = 507$; Riccelli et al., 2017). There were statistically significant differences between the two samples in age (29.2 years vs. 28.5 years; $t = 3.27$, $p = .001$; Cohen's $d = .19$), race ($\chi^2 = 67.32$, $p < .001$), and ethnicity ($\chi^2 = 10.31$, $p < .006$). No other demographic factors differed between samples. Additionally, there were no significant differences in any FFM traits between the samples (all $p > .1$, Cohen's $d < .1$). All participants provided informed consent (Van Essen, Smith, *et al.*, 2013). Exclusion criteria included a history of severe psychiatric (e.g., schizophrenia), neurological (e.g., traumatic brain injury), or medical

disorders (e.g., cardiovascular disease, Mendelian genetic disease. Additionally, participants did not have any MRI contraindications such as unsafe metal implants or claustrophobia (for full details of inclusion and exclusion criteria, see Van Essen, Ugurbil, et al., 2013).

Materials and Procedures

NEO-FFI. The NEO-FFI is a self-report measure of FFM personality traits that includes 60 items (Costa and McCrae, 1992). Cronbach's α ranged from .74 to .83 in the original sample, .76 to .85 in the replication sample, and .75 to .84 in the full sample. In the full sample, intercorrelations ranged from $r = -.40$ (Neuroticism-Conscientiousness) to .28 (Extraversion-Agreeableness). Of note, an error was detected in the calculation of Agreeableness in the Human Connectome Project download (see <https://www.mail-archive.com/hcp-users@humanconnectome.org/msg06006.html> for the correspondence regarding the error). We corrected this error by recalculating the Agreeableness score.

Voxelwise Cortical Surface Analysis. Cortical surface voxelwise analysis was used to assess the relationship of brain structure with FFM traits voxel-by-voxel in an atheoretical approach described by Fischl and Dale (Dale *et al.*, 1999; Fischl *et al.*, 1999) and utilized in recent HCP studies on brain structure (Owens *et al.*, 2017; Riccelli *et al.*, 2017). In the first step of this procedure cortical surfaces of the brains of individual subject are divided into voxels using triangular tessellation, with each voxel associated with a specific value representing the gray matter volume, cortical surface area, or cortical thickness at that voxel. Voxels in this approach are pyramidal in order to map them onto a 2D surface (whereas traditional voxel based morphometry uses 3D cubic voxels). Then subjects' brains are aligned based on the patterns of cortical surface features (e.g., sulci and gyri) and transformed into a standard space, and spatially smoothed with a 10 mm full width half maximum Gaussian kernel. Then voxel-by-voxel general

linear modeling is completed to determine cluster of voxels for which there is a significant correlation between a metric of brain morphometry (e.g., cortical thickness, cortical surface area, gray matter volume) and FFM traits. Clusterwise correction for multiple comparisons are then completed using Monte Carlo simulations (Hagler *et al.*, 2006). In this process, data are tested against a null distribution of maximum cluster size with an initial cluster-forming threshold of $p < .05$. This yields clusters corrected for multiple comparisons based on the total number of comparisons on the surface. Using this method, regions in which gray matter volume, cortical surface area, and cortical thickness are associated with FFM traits at a cluster corrected p-value of less than .05 are determined. For further explanation of the interpretation of voxelwise cortical surface analyses, see Winkler et al., 2012 (Winkler *et al.*, 2012).

Consistent with the work of Riccelli and colleagues (2017), in order to correct for their confounding effects on head size and personality, analyses were conducted with total intracranial volume, age, and sex as covariates. In our reported analyses, we opted not to control for the other FFM traits, which was done by Riccelli et al. (Riccelli *et al.*, 2017) as discussed in the Introduction and Discussion sections. However, we re-ran the analyses in the full sample using the other FFM traits as covariates, which is reported in Supplemental Table 1 and Supplemental Figures 1 through 5.

Results

Current Partial Sample Analyses

Neuroticism. In the original sample, clusters of positive correlation were found between Neuroticism and cortical thickness in the left and right DLPFC, VLPFC, and lateral parietal lobule, as well as a cluster in the right DMPFC. However, in the replication sample, the only significant association found between Neuroticism and thickness was a cluster of positive

correlation in the left DMPFC. Additionally, in the original sample, clusters of negative correlation between Neuroticism and surface area were found in the left and right lateral temporal lobe, the left cuneus, and right DLPFC and DMPFC. In the replication sample, the only cluster of negative correlation was found in the right DLPFC and DMPFC for surface area. Furthermore, in the original sample clusters of negative correlation between Neuroticism and volume were found in the right DLPFC and the left cuneus. However, in the replication sample, these clusters were not found.

Extraversion. In the original sample, a cluster of negative correlation was found between Extraversion and volume in the right superior temporal gyrus. In the replication sample, a cluster of positive correlation was found between Extraversion and thickness in the right superior temporal gyrus.

Openness. In the original sample, clusters of negative correlation were found between Openness and cortical thickness in the left and right DLPFC. In the replication sample, similar clusters of negative correlation were found with similar effects. Additionally, in the original sample, clusters of positive correlation between Openness and area were found in the left inferior temporal cortex and the right lateral occipital cortex (a left inferior temporal cluster was found for volume as well). However, in the replication sample, analogous clusters were not significant.

Agreeableness. In the original sample (Supplemental Table 2), clusters of negative correlation of Agreeableness with thickness were found in the left and right DLPFC. In the replication sample (Supplemental Table 3), a similar negatively associated cluster was found in the left hemisphere only. However, in the replication sample, clusters of positive correlation were found in the right DLPFC/precentral gyrus for area and volume.

Conscientiousness. In the original sample, a cluster of positive correlation of Conscientiousness with volume was found in the left cuneus. However, in the replication sample, this cluster was not found. Instead, two clusters of positive correlation in the left DLPFC and one in the right VLPFC/medial prefrontal cortex were found for Conscientiousness and thickness.

Full Sample Analyses

Neuroticism. In the full sample (Table 2), for Neuroticism, a cluster of positive correlation was found spanning the DLPFC and dorsomedial prefrontal cortex for thickness in both the right and left hemisphere, and a cluster was found in the left hemisphere only in the precentral gyrus and the inferior parietal lobule (Figure 1). Additionally, clusters of negative correlation were found for Neuroticism with area in the left and right DLPFC and cuneus, and with volume in the left cuneus. Table 3 displays the overlap of findings from the original sample, the replication sample, and the full sample.

Extraversion. For Extraversion, a cluster was found for volume in the right precentral gyrus (Figure 2).

Openness. For Openness, a cluster of negative correlation with cortical thickness were found spanning the DLPFC, dorsomedial prefrontal cortex, and ventrolateral prefrontal cortex in both the right and left hemisphere, as well as a cluster of negative correlation in the left angular gyrus (Figure 3). For the correlation of volume and area with Openness, a cluster of positive correlation was found in the right lateral occipital cortex, as well as a cluster in the inferior temporal gyrus for volume only.

Agreeableness. Clusters of association with Agreeableness were found for thickness in the left and right DLPFC/Precentral Gyrus (Figure 4). For the correlation of Agreeableness, clusters were found for area and volume in the right DLPFC/Precentral Gyrus.

Conscientiousness. For Conscientiousness, a cluster was found in the right temporal parietal junction for volume and area (Figure 5).

Discussion

The FFM has been used as a framework for understanding a wide range of important outcomes (Ozer and Benet-Martínez, 2006), but research into the neuroanatomical structures underlying FFM traits has been generally limited by inconsistent methodologies and small samples. The current study was designed to conceptually replicate and extend the results of Riccelli and colleagues (2017) in an independent sample of comparable size drawn from the same population using the same acquisition methods, and then aggregate the results of their original sample and the replication sample. The data from the full sample (N=1104) represent the largest investigation of the structural morphometry of personality to date, and contribute substantially to our understanding of how latent constructs like personality traits manifest physiologically.

The findings that showed consistency across the full, original, and replication samples pertained to the neuroanatomical correlates of Neuroticism, Agreeableness, and Openness. Openness was associated with thinner left and right DLPFC, Agreeableness was linked to thinner left DLPFC, and Neuroticism was associated with larger left and right DLPFC surface area in the full sample and each subsample. There were also several associations found in the full sample and one of the two subsamples but not the other. These included: 1) positive associations of Openness with area and volume in clusters in the posterior lateral temporal lobe (i.e., temporoparietal junction) and the lateral occipital cortex, which were found in the original sample and the aggregated sample; 2) positive associations of Agreeableness with area and volume in the right DLPFC found in the replication sample and aggregated sample; 3) a negative

association of Neuroticism and volume in the left cuneus found in the original sample and aggregated sample; 4) and a positive correlation between Neuroticism and cortical thickness in the left and right DLPFC and DMPFC found in the original sample and the aggregated sample. Additionally, there were findings which were significant in the full sample only, suggesting a small sized effect detectable only with a very large sample: a negative correlation of Extraversion and volume in the right DLPFC and negative correlations of Conscientiousness with area and volume in the right temporal parietal junction.

Many of the associations were found consistently across the subsamples and full sample were in the DLPFC across the traits of Neuroticism, Agreeableness, and Openness, and associations of personality with the DLPFC had the largest effect sizes in the aggregated sample. The DLPFC's status as the strongest morphometric correlate of personality is not surprising, as it is implicated in a numerous and diverse array of cognitive abilities (Duncan and Owen, 2000). This region is considered to be integral to the performance of tasks requiring executive functioning (Niendam *et al.*, 2012). Dysfunction of the DLPFC is thought to play a key role in depression (Koenigs and Grafman, 2009), which many empirical approaches to mental illness consider to be underlain by the trait of Neuroticism (Kotov *et al.*, 2017). Transcranial magnetic stimulation of the DLPFC has been demonstrated to improve depression symptoms, reduce craving for addictive substances, and improve decision making (O'Reardon *et al.*, 2007; Cho *et al.*, 2010; George *et al.*, 2010; Li *et al.*, 2013; Berlim *et al.*, 2014; Brunoni *et al.*, 2017). Thus, the relationship of the structure of the DLPFC with Neuroticism, Agreeableness, and Openness may be the result of one of many functions for which the DLPFC is integral. Of note, we were surprised that Conscientiousness was not linked to DLPFC structure, which would have been consistent with theoretical accounts of (low) Conscientiousness as a trait akin to impulsivity and

related to difficulties with response inhibition (Wiggins, 1996; Whiteside and Lynam, 2001).

Previous, small VBM studies have found gray matter volume in the DLPFC to relate to Conscientiousness (DeYoung *et al.*, 2010), but the current investigation provides relatively weak support for this association, with only one of the two samples finding an association of DLPFC thickness with Conscientiousness and such association not being present in the aggregated sample. However, in the alternate version of the current analyses which controlled for the other FFM traits in the full sample (presented in Supplemental Table 1), there were clusters of positive correlation between Conscientiousness and thickness in the left and right DLPFC, and negative correlations between Conscientiousness and area in the right DLPFC and dorsomedial prefrontal cortex and the left inferior temporal gyrus. This may indicate that relationship of Conscientiousness to the DLPFC found when controlling for the other traits is primarily a suppression effect due to controlling for other traits, and that on its own Conscientiousness does not have a particular relationship with brain morphometry.

Other regions implicated in at least one subsample and the full sample include the posterior parietal cortex (i.e., inferior and superior parietal lobule), the cuneus, the inferior temporal cortex, the temporal parietal junction, and the lateral occipital lobe. The posterior parietal cortex has been implicated in numerous functions including logical reasoning, mathematical cognition, spatial mapping, working memory, episodic memory retrieval, and attention (Behrmann *et al.*, 2004; Todd and Marois, 2004; Wagner *et al.*, 2005; Wendelken, 2015). The cuneus and the rest of the occipital lobe is traditionally associated with visual processing (Vanni *et al.*, 2001), but there has been some evidence that the cuneus may be involved in “higher-order” cognitive functions such as behavioral inhibition (Haldane *et al.*, 2008) and working memory (Owens *et al.*, 2018). The lateral temporal lobe (including the

inferior temporal gyrus) is involved in sensory processing (vision and hearing) and is also considered a secondary part of the default mode network (Goodale and Milner, 1992; Vanni *et al.*, 2001; Zatorre and Belin, 2001; Andrews-Hanna *et al.*, 2010). The temporoparietal junction is involved in sensory integration (Tsakiris *et al.*, 2008), as well as diverse other cognitive abilities such as meta-cognition (Fox *et al.*, 2015), making moral judgements (Sellaro *et al.*, 2015), theory of mind (Samson *et al.*, 2004), and social interactions (Decety and Lamm, 2007). The lateral occipital cortex has almost exclusively been associated with visual processing in prior work (e.g., Larsson & Heeger, 2006) making its relationship to personality difficult to speculate on.

Considerations and Conclusions

A primary consideration for integrating this investigation with the current literature is a key difference in analytical technique from that implemented by Riccelli and colleagues (2017) in that we did not control for the other FFM traits, while the previous study by Riccelli *et al.* did control for them. However, we also completed the analyses in the full sample controlling for the other traits, which are reported in Supplemental Table 1 and Supplemental Figure 1. That there were meaningful differences between the two approaches, particularly in morphometric correlates of Conscientiousness, highlights the need for consideration by the field of personality neuroscience regarding which approach is more appropriate. We think that *not* controlling for the other FFM traits is a preferable analytic approach, since there are documented difficulties in interpreting the relations of partialled personality variables with criterion variables from their broader nomological network (Lynam *et al.*, 2006; Sleep *et al.*, 2017).

Another important consideration of the current work relates to the sample and the generalizability of these findings given that the current sample comprised relatively young, healthy adults from the United States. Similar efforts are needed in more diverse (in terms of age,

race, ethnicity) samples, as recent research studying the morphometric correlates of complex behaviors have found differing neural correlates between adolescents and adults. For example, two large sample studies of the morphometric correlates of delayed reward discounting found substantially different regions underpinning delayed reward discounting when studied in adults (Owens *et al.*, 2017) and adolescents (Mackey *et al.*, 2017). While there were also differences in methodology (one of these two studies used VBM and the other used SBM), this incongruity suggests the possibility of significant differences between adults and adolescents in morphometric correlates of complex behaviors.

In sum, the current study emphasizes the difficulty in parsing the nature of the relationship between structural measures of the brain and personality traits. Even in adequately powered studies using state-of-the-art acquisition and analysis methods, the current research highlights the challenge of uniting latent constructs like personality traits with physiological indicators. The current results suggest that there are numerous cortical structures that are relevant to personality, and the structure of the DLPFC appears to play a role in the neuroanatomical underpinnings of personality traits. However, further research is needed to understand how morphometric differences in the DLPFC affect neural functioning.

In addition to providing the largest scale investigation into the morphometric correlates of personality traits to date, the current study contributes to our understanding of the replicability of personality neuroscience findings broadly. Despite an increasing awareness of the crisis of replicability in social science (Ioannidis, 2005; Simmons *et al.*, 2011; Button *et al.*, 2013; Miguel *et al.*, 2014), many seminal studies have not been reanalyzed or replicated. Despite the strengths of the study by Riccelli and colleagues (2017), including an unusually large sample size for a neuroimaging manuscript and state of the art data acquisition and analysis methods, more than

half of the clusters identified in their sample were not found in an independent sample of similar size drawn from the same population using almost the exact same methods. Furthermore, more than a third of the regions found in the original sample did not replicate in the aggregated analysis including both samples. Based on the very high quality of the original study (i.e., advanced methodology, large sample size), this outcome likely represents the more optimistic end of the spectrum of replicability; in other words, it is likely that attempts to replicate other seminal morphometric correlation studies using smaller and demographically different samples would detect even fewer replicable findings. Thus, while this is not the first time a study has used SBM to test the morphometric correlates of personality in healthy adults, it is one of the first instances in which a large initial study has been reanalyzed and (partially) replicated in a much larger sample. The current findings suggest regions whose structure is most related to personality, but more importantly, they accentuate the importance of statistical power and replication to the future of personality neuroscience research.

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Table 1

Demographic characteristics of the original sample, the replication sample, and the combined samples. * indicates statistically significant differences between original and partial sample ($p < .05$).

	Original Sample (n=507)	Replication Sample (n=597)	Full Sample (N=1104)
Sex			
Male	40.6%	50.1%	45.7%
Female	59.4%	49.9%	54.3%
Age*	29.2 (3.5)	28.5 (3.8)	28.8 (3.7)
Race*			
White or Caucasian	72.6%	76.5%	74.7%
Black or African American	22.3%	9.0%	15.1%
Asian American	1.8%	9.0%	5.7%
Native American	0.0%	.3%	.2%
More than one race	1.2%	3.7%	2.5%
Not sure or unknown	2.2%	1.3%	1.7%
Ethnicity*			
Hispanic or Latino	10.1%	7.6%	8.5%
Not Hispanic or Latino	89.7%	90.8%	90.3%
Not sure or unknown	.2%	2.0%	1.2%
Income			
\$1,000-\$9,999/year	7.9%	6.4%	7.1%
\$10,000-\$19,999/year	7.7%	8.0%	7.9%
\$20,000-\$29,999/year	13.6%	11.4%	12.5%
\$30,000-\$39,999/year	10.8%	12.9%	12.0%
\$40,000-\$49,999/year	10.8%	9.7%	10.3%
\$50,000-\$74,999/year	18.7%	22.9%	21.1%
\$75,000-\$99,999/year	15.4%	11.6%	13.4%
\$100,000-\$149,999/year	14.4%	16.4%	15.6%
Years of Education	14.8	15.0 (1.7)	14.92 (1.80)

Note: demographic information is presented as Mean (Standard Deviation) or as a percentage.

Table 2

Significant clusters of brain by FFM trait correlation from full sample ($N = 1104$). Age, sex, and total intracranial volume were modeled as covariates. Max = maximum p -value in cluster, $-\log_{10}$ transformed; Size = cluster size in mm^2 ; X, Y, Z coordinates in MNI space; CWP = clusterwise probability. DLPFC = dorsolateral prefrontal cortex; DMPFC = dorsomedial prefrontal cortex; VLPFC = ventrolateral prefrontal cortex; TPJ = temporal parietal junction. CPW of .000 represents a clusterwise probability of $< .001$.

FFM Trait	Metric	Region	Max	Size	X	Y	Z	CWP
Neuroticism	LH Thickness	DLPFC/VLPFC/ DMPFC/Precentral	5.33	7846	-11	30	51	0.000
		Precentral/Inferior Parietal	3.72	1728	-56	-2	8	0.000
	RH Thickness	DLPFC/DMPFC	4.53	2631	-36	14	33	0.000
		DLPFC	3.83	1210	-24	38	33	0.007
	LH Area	DLPFC	-4.32	2922	-10	25	57	0.000
		Cuneus	-3.33	2730	-4	-85	13	0.000
		Inferior Temporal	-2.81	1436	-44	-13	-37	0.023
	RH Area	DLPFC/DMPFC	-4.87	4500	-37	24	22	0.000
		Cuneus	-2.87	1453	-40	-75	21	0.035
	LH Volume	Cuneus	-2.97	2079	-11	-85	1	0.000
Extraversion	RH Volume	Precentral Gyrus	3.26	1184	-49	-2	34	0.008
Openness	LH Thickness	DLPFC/VLPFC/ DMPFC/Precentral	-4.88	7275	-15	57	17	0.000
		Superior Parietal Lobule	-4.70	1143	-17	-76	39	0.011
		Inferior Parietal Lobule	-3.03	1005	-48	-60	41	0.024
	RH Thickness	DLPFC/VLPFC /DMPFC	-4.08	4615	-37	35	29	0.000
	LH Area	Inferior Temporal	2.97	1421	-49	-11	-36	0.025
	RH Area	Lateral Occipital	3.24	1438	-23	-87	-12	0.036
	LH Volume	Inferior Temporal	2.76	919	-36	-4	-42	0.044
	RH Volume	Lateral Occipital	3.56	1057	-18	-91	-8	0.018
Agreeableness	LH Thickness	DLPFC/precentral	-4.50	1481	-38	20	45	0.001
		DLPFC/precentral	-4.34	2860	-21	23	56	0.000
	RH area	DLPFC/precentral	4.25	1567	-20	4	54	0.022
	RH Volume	DLPFC/precentral	3.00	1089	-19	12	55	0.014
Conscientiousness	RH Area	TPJ	-3.02	1688	-6	-87	32	0.014
	RH Volume	TPJ	-4.03	985	-6	-86	28	0.028

Table 3

Brain by personality correlations across the two samples and the aggregated sample.

FFM Trait	Metric	Region	N = 507	N = 597	N = 1104
Neuroticism	LH Thickness	Lateral Frontal	X		X
		Medial Frontal		X	X
		Lateral Parietal	X		X
	RH Thickness	Lateral Frontal	X		X
		Medial Frontal	X		X
		Lateral Parietal	X		
		Lateral Temporal	X		
	LH Area	Lateral Frontal		X	X
		Lateral Temporal	X		X
		Medial Occipital	X		X
	RH Area	Lateral Frontal	X	X	X
		Lateral Parietal			X
		Lateral Temporal	X		
	LH Volume	Medial Occipital	X		X
	RH Volume	Lateral Frontal	X		
Extraversion	RH Thickness	Lateral Temporal	X		
	RH Volume	Lateral Temporal		X	
		Lateral Frontal			X
Openness	LH Thickness	Lateral Frontal	X	X	X
		Lateral Parietal			X
	RH Thickness	Lateral Frontal	X	X	X
		Lateral Parietal	X		
	LH Area	Lateral Temporal	X		X
	RH Area	Lateral Occipital	X		X
	LH Volume	Lateral Temporal	X		X
	RH Volume	Lateral Occipital			X
Agreeableness	LH Thickness	Lateral Frontal	X	X	X
	RH Thickness	Lateral Frontal	X		
	RH Area	Lateral Frontal		X	X
	RH Volume	Lateral Frontal		X	X
Conscientiousness	LH Thickness	Lateral Frontal		X	
	RH Thickness	Lateral Frontal		X	
	RH Area	Temporal Parietal			X
	LH Volume	Medial Occipital	X		
	RH Volume	Temporal Parietal			X

Figure 1

Clusters of significant correlation between brain metrics and Neuroticism in the full sample (N=1104). Panels A and B show left hemisphere cortical thickness (lateral and medial view), Panels C and D show right hemisphere cortical thickness. Panels E and F show left hemispheres cortical surface area (lateral and medial). Panels G and H show right hemisphere cortical thickness (lateral and medial). Panel I shows left hemisphere gray matter volume. Red = positive correlation; Blue = negative correlation.

C

D

E

F

G

H

I

Figure 2

Clusters of significant correlation between right hemisphere gray matter volume and Extraversion in the full sample (N=1104). Red = positive correlation; Blue = negative correlation.

Figure 3

Clusters of significant correlation between brain metrics and Openness in the full sample (N=1104). Panels A and B show left hemisphere cortical thickness (lateral and medial view), Panels C and D show right hemisphere cortical thickness. Panels E and F show left and right hemispheres cortical surface area. Panels G and H show left and right hemispheres gray matter volume. Red = positive correlation; Blue = negative correlation.

C **D**

E

F

G

H

Figure 4

Clusters of significant correlation between brain metrics and Agreeableness in the full sample (N=1104). Panel A shows left hemisphere cortical thickness, Panel B shows right hemisphere cortical surface area. Panel C shows right hemisphere gray matter volume. Red = positive correlation; Blue = negative correlation.

C

Figure 5

Clusters of significant correlation between brain metrics and Conscientiousness in the full sample (N=1104). Panel A shows right hemisphere cortical surface area, Panel B shows right hemisphere gray matter volume. Red = positive correlation; Blue = negative correlation.

A **B**